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IN THE

Supreme Court of the United States

October Term, 1962

No. 558

AERONAUTICAL COMMUNICATIONS EQUIPMENT, INC.,
Petitioner,

v.

HELEN RUSSELL PIERCE, Executrix of the Last Will and Testament of GEORGE WASHINGTON PIERCE, Deceased,
Respondent.

APPENDICES A - M
TO
PETITION FOR WRIT OF CERTIORARI

WALTER H. FREE
Attorney for Petitioner
90 Broad Street
New York 4, New York

BRUMBAUGH, FREE, GRAVES & DONOHUE
JOHN F. NEARY, JR.
FRANK W. FORD, JR.
90 Broad Street
New York 4, New York

SYDNEY L. WEINTRAUB
Security Trust Building
Miami 32, Florida

Of Counsel for Petitioner

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APPENDIX A

Decision of U. S. Court of Appeals, Fifth Circuit

(Decided September 6, 1962)

IN THE

UNITED STATES COURT OF APPEALS

FOR THE FIFTH CIRCUIT

No. 19422

HELEN RUSSELL PIERCE, Executrix of the Last Will and Testament of GEORGE WASHINGTON PIERCE, Deceased,

Appellant,

versus

AERONAUTICAL COMMUNICATIONS EQUIPMENT, INC.,

Appellee.

Appeal from the United States District Court for the Southern District of Florida.

(September 6, 1962)

Before TUTTLE, Chief Judge, BELL, Circuit Judge, and CARSWELL, District Judge.

TUTTLE, Chief Judge:

We undertake here to present what we consider to be the fairly narrow issue that remains to be decided in this extended and hard-fought litigation. We do this by assuming the correctness of all of the contentions of the appellee except the ultimate conclusion of law which remains for

our decision. The issue can be posed as a question: If an inventor obtains a *combination* patent in the area of radio communication, which *combination* consists of a transmitting and receiving system, each of which, that is, both the transmitting part and the receiving part, includes an *element* known as an "oscillator," and the same inventor obtains a separate patent, applied for at the same time but issued some seven years later, on the oscillator itself, is the patent on the oscillator void for double patenting if it be assumed that its inclusion in each the transmitting and receiving parts of the combination patent was the essential element without which the combination patent would not have issued? In posing the question it must be made clear that in the *combination* patent no separate claim was made as such for the oscillator, each of the three claims of the patents being in terms "a transmitting and receiving system having, in combination, means for transmitting signal waves, means for receiving the signal waves, etc."

This Court has previously given consideration to the contentions now advanced by the parties when the case was here on an appeal from the grant by the trial court of a motion for summary judgment for the defendant, which was entered by it upon the "reasoning" of the Court of Appeals for the First Circuit in two earlier cases involving the same patents, *Pierce* v. *Aeronautical Communications Equipment Co.*, 5 Cir., 255 F. 2d 458. We there held that, notwithstanding the decision of a court of a different circuit for which we have the highest respect, the inventor was entitled to have the validity of his patent passed on in a case against a different alleged infringer as to all factual matters as well as on the legal issues involved by the courts of this circuit. We made reference to that earlier decision for a description of the patent now in suit, and a statement demonstrating its importance, or, at least, the importance of it, or the prior combination patent, in the art of radio commu-

nication. However, the following brief statement of facts is essential to an understanding of the question we have posed:

Professor Pierce, the appellant's decedent, was the unquestioned inventor of the Pierce oscillator which is claimed as the invention in the patent No. 2,133,642 here in issue. At the time of inventing the Pierce oscillator, Pierce invented a number of subsidiary electrical systems for which, by application of February 25, 1924, he endeavored to obtain a single patent covering them all. Since this application included not only general claims for the use of a piezo-electric crystal to control the frequency of an oscillating system (the oscillator) but also specific claims for the combination of a radio transmitter and receiver in which two of such crystals could be used, the Patent Office held[1] that more than one invention was described in the application and required a division. In compliance with this direction Pierce filed a number of additional applications and two of the resulting patents are involved in this suit. One of the additional applications matured, however, on January 20, 1931, into patent No. 1,789,496, and this patent expired in 1948, before the defendant began the infringement acts complained of in this suit.

Patent No. 1,789,496, consisting of three claims, is for a radio transmitting and receiving system in combination,

1. Much of the argument before this Court and before the other Courts in which this patent has been litigated, goes to the question whether Pierce's division of the several claims originally filed into several different applications, which resulted in several different patents, was actually required by a binding determination of the Patent Office. It is clear beyond dispute, however, that it was the Patent Office that made plain to Pierce that a patent would not issue covering all the claims which, if divided, might be the subject of separate patents. We think the record fully supports the statement made by this Court in the previous opinion to the effect that "it was the Patent Office that required the division that led to the two separate patents."

having a means of keeping the oscillations of both the transmitter and receiver at the same constant frequency. Claim 1 specifically mentions the use of a piezoelectric body for controlling the frequency of these oscillations and that would seem to allow the piezoelectric-crystal-controlled oscillators shown in the Cady patent No. 1,472,583 to be used as an element in the combined transmitting and receiving system. Claim 2 specifies the use of an electro-mechanical vibrator having two electric terminals in a single vacuum tube circuit, which circuit oscillates at a frequency widely independent of the other elements in the circuit. It thus apparently specifies the Pierce oscillator. Claim 3 is much broader in that it calls for any kind of prior art electro-mechanical vibrator to control the frequency.

Action on Pierce's other applications, which resulted from the division, was delayed because of requests for a fuller explanation of the properties of piezoelectric crystals and the failure to pay on time the required final fee. On April 20, 1930, the Patent Office issued a patent to John M. Miller covering claims 51, 52, 54, 55, 56 and 61 through 68 of Pierce's now patent No. 2,133,642. Litigation resulted in the holding that Pierce and not Miller was the inventor of the Pierce oscillator represented by the above claims. *Miller* v. *National Broadcasting Company, Inc.*, 3 Cir., 79 F. 2d 657; *Miller* v. *Pierce*, 97 F. 2d 141, 25 C. C. P. A., Patents, 1195. Thereafter, on October 18, 1938, the Pierce patents No. 2,133,642 and No. 2,133,646 and the other patent still involved in this suit, were issued.

After the expiration in 1948 of the protection provided by patent No. 1,789,496 various business concerns began to produce electrical vibrator systems, which Pierce believed infringed his later patents, which had not, by that time, expired. He entered nine suits in several different circuits against various defendants. The principal contention as to infringement here relates to the thirteen claims, 51, 52, 54,

55 and 61 through 68 of No. 2,133,642. This is the patent covering the Pierce oscillator.

The parties do not contest the basic right of a patentee, in such circumstances, to have his claims passed on by the courts of the other circuits. In *Triplett* v. *Lowell*, 297 U. S. 638, the Supreme Court said at page 645:

> "The court whose jurisdiction is involved by such a suit [i.e., a second suit in a circuit other than the circuit which has already passed on the matter] must *determine for itself* validity and ownership of the claims asserted, notwithstanding a prior adjudication of invalidity of some of them, unless those issues have become res adjudicata by reason of the fact that both suits are between the same parties or their privies." (Emphasis added)

When the case was here before, we reversed the summary judgment entered by the trial court, because it was apparent that the trial court merely adopted the decisions of the Court of Appeals for the First Circuit in *American Communications Co.* v. *Pierce*, 1 Cir., 208 F. 2d 763, and *Pierce* v. *Hewlett Packard Co.*, 1 Cir., 220 F. 2d 531, without making its own decision, to which the patentee was entitled. In reversing the case, we stated that the language of the Court of Appeals for the First Circuit in the *Hewlett Packard* case "suggests that patent number 1,789,496 was not valid at all in that it was issued for a combination radio transmitting and receiving system with claims both using and not using Pierce's oscillators." We then stated that if the '496 patent was not valid, then the defense of double patenting as to the '642 patent would be unavailing. However, the patentee's executrix, the appellant here, has now expressly waived any contention that the '496 patent was invalid. She, therefore, undertakes to meet the double patenting defense head-on.

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Decision of U. S. Court of Appeals, Fifth Circuit

As to the double patenting defense as applied in the First Circuit, we had the following to say:

> "Even if the First Circuit cases have analyzed the situation correctly, they do not proceed to the point of considering the position of a patentee who has a patent on a combination invention which includes in it a patentable element. The plaintiff in this case may be able to prove that the Pierce oscillator itself is not sufficiently described in claim 2 of patent No. 1,789,496 to provide Pierce with sufficient protection. If someone had used the Pierce oscillator in a system other than the radio system described in No. 1,789,496, the plaintiff would have had difficulties, perhaps nsurmountable, in proving that he was afforded protection under No. 1,789,496. *A patent on a combination is a patent on the functioning whole, not on the separate parts* and the fact that an unpatented element of a combination may distinguish the invention does not draw to it the privileges of a patent. Mercoid Corporation v. Mid-Continent Investment Co., 320 U. S. 661, 64 S. Ct. 268, 88 L. Ed. 376; Mercoid Corporation v. Minneapolis-Honeywell Regulator Co., 320 U. S. 680, 64 S. Ct. 278, 88 L. Ed. 396; Rowell v. Lindsay, 113 U. S. 97, 5 S. Ct. 507, 28 L. Ed. 906. (Emphasis Added)
>
> "The reasoning of the above First Circuit opinions is, moreover, opposed to the basis of the division order and places the inventor in a perplexing dilemma. He must divide his claims into separate applications for separate patents to comply with the Patent Office's requirements but when he does this he faces the prospect of losing part of his pro-

tection, if, as in this case, the patents are issued at different times, and the double patenting argument is used against him. If, as appears to be undisputed, the plaintiff did make a significant contribution with the Pierce oscillator, he is entitled to a patent on it alone to prevent its use without his consent in any combination and for the full 17 years. If the oscillator is not specifically claimed as such in patent No. 1,789,496 that patent should stand or fall as a combination patent and have no bearing on the oscillator patent No. 2,133,642; otherwise by obeying the Patent Office's order the plaintiff is denied a portion of the protection to which he is entitled.

"Since it was the Patent Office which required the division that led to the two separate patents, plaintiff does not come under the rule of Palmer Pneumatic Tire Co. v. Lozier, 6 Cir., 90 F. 732, prohibiting one from extracting an essential element of his invention from a former patent without which that patent would not have been granted and taking it for the subject of a new patent. Plaintiff originally had presented all of his claims in 1924 and because of the separation ruling and the litigation with Miller he was not awarded a final patent on the oscillator itself until 1938. He is not then in the position of one who tries to extend his coverage by taking the element from the combination for a later and separate patent. Plaintiff should now be allowed to prove that the oscillator is not specifically claimed in patent No. 1,789,496, and that at most it was only protected by that patent to the extent it was used in the combination described therein."

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Decision of U. S. Court of Appeals, Fifth Circuit

Upon remand the trial court seems to have been so preoccupied with the decisions of the Court of Appeals for the First Circuit, supra, and a subsequent one in the Third Circuit, *Pierce, Executrix,* v. *Allen B. DuMont Laboratories, Inc.*, 178 F. Supp. 84 (Dist. of Delaware), subsequently affirmed at 297 F. 2d 323, that it paid little attention to the legal principles to be gleaned from our prior opinion. Thus it is that, without doing what we expressly stated the case was remanded for—to allow the plaintiff to "prove that the oscillator is not specifically claimed in patent No. 1,789,496," the Court posed an erroneous legal question. It said, "The question simply posed requires a determination as to whether patent No. 2,133,642 contains the same element as patent No. 1,789,496, and if this question is answered in the affirmative, the legal thesis of double patent would apply which would make patent 1,789,496 a predicate for the double patenting of No. 2,133,642." Even this question, it seems to us, does not accurately state what the trial court then proceeded to consider, because obviously the combination patent, 1,789,496, contained many elements in the transmitting and receiving system that were not "contained" in patent 2,133,642, which was purely and simply a patent on the oscillator. Perhaps the Court meant to state the question to be whether "Patent No. 2,133,642 comprises *any of the same elements* as patent No. 1,789,496, and if this question is answered in the affirmative, the legal thesis of double patenting would apply, etc." If this is the question the Court undertook to answer, then it clearly conflicts with the law as laid down by our prior opinion, for we stated, "a patent on a combination is a patent on the functioning whole, not on the separate parts and the fact that an unpatented element of a combination may distinguish the invention does not draw to it the privileges of a patent." Yet the trial court held that since the Pierce

oscillator "distinguished the invention," to use our earlier language, or was the "essential element" of the combination patent, to use the language of the trial court, the patent on the oscillator must fail on the basis of double patenting.

Moreover it is clear that the trial court completely ignored that part of our earlier opinion quoted above dealing with the case of *Palmer Pneumatic Tire Co. v. Lozier*, 6 Cir., 90 Fed. 732, where we said that the plaintiff here "does *not* come under the rule of Palmer Pneumatic Tire Co. v. Lozier, 6 Cir., 90 Fed. 732, prohibiting one from extracting an essential element of his invention from a former patent, without which that patent would not have been granted, and taking it for the subject of a new patent." Ignoring this prior holding, the trial court said, "Pierce cannot extract this essential element and make it the basis of a subsequent patent, since the Pierce oscillator, the subject of patent No. 2,133,642, rather than the production of a constant beat, is the essential distinguishing feature of combination patent 1,789,496."

The Supreme Court has written fairly recently on the plain distinction between a combination patent and its elements. The latest word on this subject comes from *Aro Manufacturing Co. v. Convertible Top Company*, 365 U. S. 336, where, on page 344, the Court says:

> "For if anything is settled in the patent law, it is that the combination patent covers only the totality of the elements in the claim, and that no element, separately viewed, is within the grant," citing Mercoid Corp. v. Mid Continent Co., supra.

The Court then proceeds to say:

> "The basic fallacy in respondent's position is that it requires the ascribing to one element of the patented combination, the status of patented invention

> itself. Yet this Court has made it clear in the two Mercoid cases that there is no legally recognizable or protected 'essential' element, 'gist,' or 'heart' of the invention in a combination patent."

Referring to the *Mercoid* case, we find the following language:

> "* * * We now add that it makes no difference that the unpatented device is part of the patented whole.
>
> "That result may not be obviated in the present case by calling the combustion stoker switch the 'heart of the invention,' or 'the advance in the art.' The patent is for a combination only, since none of the separate elements of the combination is claimed as the invention, none of them, when dealt with separately, is protected by the patent monopoly."

So here, since the Pierce oscillator is not claimed as the invention, it is not "protected by the patent monopoly" in the combination patent. This being true, the patent subsequently issued on the oscillator cannot be held to be void for double patenting because it has never been patented before.

It is not contended by the appellee, here the alleged infringer, that the delay in the issuing of the 642 patent was accomplished in any manner that in and of itself subjected it to an attack on its validity. We have pointed out that it is also not seriously disputed that the division of the original paatent into the several that subsequently gave rise to the charge of double patenting was upon the suggestion, if not the direction, of the Patent Office. To the extent then that the decisions of the other courts which have passed on this question are based on the idea that the patentee in some manner improperly or inequitably extended the period of his monopoly on the Pierce oscillator by causing it

to be issued seven years later than the combination patent which embodied it as one of its elements, we find no authority for thus limiting the rights of a patentee. Either the '642 patent is valid, as clearly claiming a patentable invention[2] or it was invalid because it was the subject of a prior patent, which, of course, would be patent '496. Since however, as we have pointed out, the Supreme Court has repeatedly held that no separate *element* of a combination patent is given any monopoly under the patent laws, but only the *combination as a whole* is protected, there can be no double patenting where the patent issued subsequently constitutes one of the elements of the combination patent.

What we have heretofore said with respect to the thirteen claims to the '642 patent applies even more strongly with respect to the other of the two subsequent patents still at issue here, No. 2,133,646. As to these, the trial court made no effort to analyze the respective claims, or to determine whether claims 5, 9, 16, 22 and 23 of '646 were covered by any of the three claims of 1,789,496. The court simply said, "No useful purpose could be served by setting forth in detail the nature and the basis of the patent which is being discussed since, in my judgment, the validity has been most learnedly and thoroughly considered by other courts whose conclusions I am impelled to follow. The invalidity of the patent on the thesis of double patenting is therefore adjudicated on the basis of the following authorities: 159 F. Supp. 943, Dist. of Mass., 280 F. 2d, 1 Cir. '78, and 178 F. 2d 84, Dist. of Delaware." Ignoring, therefore, the express mandate of this court on the subject matter, the trial judge denied the patentee the right which all parties have consistently agreed he has, that is to an in-

2. Every court that has passed on any of these patents has recognized that, standing alone, this '642 patent would be a valid patent because of the very substantial contribution made to the art by the Pierce oscillator.

pendent consideration of the validity of the patent by the trial court in this circuit, *Triplett* v. *Lowell, supra*, and this it did notwithstanding the mandate of this court expressly directing it to consider the question whether the Pierce oscillator was specifically claimed in patent No. 1,789,496.

Having concluded that the trial court erred in holding that the thirteen claims of 2,133,642, and the five claims of 2,133,646 were void or invalid for double patenting, was error, we now decide that, the said defenses having failed, the said claims of the two patents are valid. The case is now remanded to the trial court for the purpose of determining whether the appellee infringed these two patents and for further proceedings not inconsistent with this opinion.

REVERSED and REMANDED.

Appendix A

Judgment of United States Court of Appeals, Second Circuit, Dated September 6, 1962

UNITED STATES COURT OF APPEALS

FOR THE FIFTH CIRCUIT

October Term, 1961

No. 19,422

D. C. Docket No. 5638-M-Civil

HELEN RUSSELL PIERCE, Executrix of the Last Will and Testament of GEORGE WASHINGTON PIERCE, Deceased,
Appellant,

versus

AERONAUTICAL COMMUNICATIONS EQUIPMENT, INC.,
Appellee.

Appeal from the United States District Court for the Southern District of Florida.

Before Tuttle, Chief Judge, Bell, Circuit Judge, and Carswell, District Judge.

JUDGMENT

This cause came on to be heard on the transcript of the record from the United States District Court for the Southern District of Florida, and was argued by counsel;

Appendix A

Judgment of U. S. Court of Appeals, Second Circuit

ON CONSIDERATION WHEREOF, It is now here ordered and adjudged by this Court that the judgment of the said District Court in this cause be, and the same is hereby, reversed; and that this cause be, and it is hereby, remanded to the said District Court for the purpose of determining whether the appellee infringed these two patents, 2,133,642 and 2,133,646, and for further proceedings not inconsistent with the opinion of this Court;

It is further ordered and adjudged that the appellee, Aeronautical Communications Equipment, Inc., be condemned to pay the costs of this cause in this Court for which execution may be issued out of the said District Court.

September 6, 1962

Issued:

APPENDIX B

Decision of U. S. District Court, Southern District of Florida

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Helen Russell Pierce, Executrix of the Last Will and Testament of George Washington Pierce, Deceased,
Plaintiff,

v.

Aeronautical Communications Equipment, Inc.,
Defendants.

Civ. A. No. 5638-M.

United States District Court
S. D. Florida,
Miami Division.

June 15, 1961.

On Motion for Modification

Aug. 11, 1961.

Gourley, District Judge.

This protracted patent litigation relates to a group of five now expired patents which involve electrical systems and apparatus for use primarily in the science of radio communication through constant high-frequency radio waves:

Original application 695,094 was filed February 25, 1924. This application was subject to Order of Division by Patent Office. Pierce elected to file separate patent applications which were granted:

Patent 1,789,496 issued January 20, 1931
Patent 2,133,642 issued October 18, 1938
Patent 2,133,643 issued October 18, 1938

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Decision of U. S. District Court, S. D. of Florida

Patent 2,133,645 issued October 18, 1938
Patent 2,133,646 issued October 18, 1938
Patent 2,133,648 issued October 18, 1938
Patent 2,266,070 issued October 18, 1938

The case is presented to the court through cross-motions for summary judgment.

All matters to be considered and records in other courts have been stipulated.

Summary judgment consideration is proper since the question of infringement and/or validity of the patents involved must be determined as a matter of law.

The Court has given a full and complete opportunity to the parties to present lay or expert evidence and testimony, documents and exhibits relative to all patents. In addition, all directives were followed as enunciated in Pierce v. Aeronautical Communications Equipment, Inc., 5 Cir., 255 F. 2d 458.

Plaintiff has elected to proceed only as to Patent 2,133,642 and only thirteen claims thereof: Claims 51, 52, 54, 55, 56 and 61 to 68 inclusive.

At time of trial and hearing, Patents 2,133,643, 2,133,645, 2,133,646 and 2,133,648 were withdrawn from consideration of Court. Patent 2,266,070 was previously withdrawn from Court's consideration. Pierce v. Aeronautical Communications Equipment, Inc., supra.

Wading through the maze of records, documents, affidavits and legal expositions, succinctly stated, the sole question for the Court is as follows:

Are the thirteen claims of Patent 2,133,642 invalid on the thesis of double patenting when evaluated with Patent 1,789,496?

And if the answer is "No"—

Did the defendant infringe any or all of the thirteen claims of Patent 2,133,642 by manufacturing, using and sell-

Appendix B

Decision of U. S. District Court, S. D. of Florida

ing electrical and electromechanical vibrator systems and apparatus including the Pierce oscillator?

There have been many chapters written in this involved, prolonged and interesting patent litigation.[1] I think it would be acts of plagiarism to restate what has been so thoroughly and intelligently expressed by other courts.

It has been concluded and consistently held that the thirteen claims of Patent 2,133,642 are invalid for double patenting over Patent 1,789,496.[1]

Furthermore, the rule against double patenting is based upon the idea that the power to create a monopoly is exhausted by the first patent, and that a new and later patent for the same invention would operate to extend or prolong

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1. Case 1: American Communications Co., Inc. v. Pierce, 1 Cir., 1953, 208 F. 2d 763; certiorari denied 1954, 347 U. S. 944, 74 S. Ct. 639, 98 L. Ed. 1092; rehearing denied 1954, 347 U. S. 970, 74 S. Ct. 775, 98 L. Ed. 1111; reversing Pierce v. American Communications Co., Inc., D. C. D. Mass. 1953, 111 F. Supp. 181, Judge Ford.

Case 2: Pierce v. Hewlett-Packard Co., D. C. D. Mass. 1954, 125 F. Supp. 329, Judge Wyzanski; affirmed 1 Cir., 1955, 220 F. 2d 531; certiorari denied 1955, 350 U. S. 833, 76 S. Ct. 69, 100 L. Ed. 744, rehearing denied 1955, 350 U. S. 897, 76 S. Ct. 149, 100 L. Ed. 789.

Case 3: Pierce v. American Communications Co., Inc. (Pierce v. Mackay Radio & Telegraph Inc.), D. C. D. Mass. 1959, 159 F. Supp. 943, Judge Ford.

Case 4: Pierce v. Aeronautical Communications Equipment, Inc., Order of Judge Choate granting summary (and final) judgment (S. D. Florida, Miami Division No. 5638-M Civil, 1957) case reversed and remanded for further proceedings. 5 Cir., 1958, 255 F. 2d 458.

Case 5: Pierce v. American Communications Co., Inc. (Pierce v. Mackay Radio & Telegraph Co.), D. C. D. Mass. 1958, 169 F. Supp. 351, Judge Ford.

Case 6: Pierce v. American Communications Company, Inc., 1 Cir., 1960, 280 F. 2d 278.

Case 7: Pierce v. Allen B. DuMont Laboratories, Inc., D. C. D. Del. 1959, 178 F. Supp. 84.

the monopoly beyond the period allowed by law. J. R. Clark Co. v. Jones & Laughlin Steel Corp., 7 Cir., 288 F. 2d 279.

I agree with the well-reasoned conclusions heretofore reached, so consistently, by my eminent brethren in other courts.

The motion for summary judgment of the defendant as to Patents 2,133,643, 2,133,645, 2,133,646, 2,133,648 and 2,266,070 and all their claims is granted for lack of prosecution by the plaintiff.

The motion for summary judgment of the defendant as to Patent 2,133,642 and Claims 51, 52, 54, 55, 56 and 61 to 68, inclusive, is granted.

The motion for summary judgment of the plaintiff as to all patents and claims is refused.

Prior Art and History of Patent Purposes

The prior art indicates that scientific means to attain constant frequency had been found to generate electrical oscillations and many efforts with much scientific knowledge had been applied to improve the means of controlling the frequency of electrical systems. The thermionic vacuum tube that was used to generate electric oscillations became heated which caused an undesirable amount of variation in the constant frequency. Pierce discovered a means whereby the frequency circuit could oscillate without employing any inductive coils or condensers and said results were attained at a remarkable constant frequency.

In the field of radio broadcasting a need had existed for controlling the frequency of oscillating electrical circuits. Radio communication is transmitted by carrier waves which are generated from the transmitter by an alternating current of electricity flowing in and out of an antenna, composed of wires suspended in the air. Radio waves are produced when the current oscillates at a high frequency. Since communication between a sender and a receiver is

possible only when both are turned to the same frequency, it is highly desirable that the frequency of the waves sent out from a transmitter remain constant.

Purposes and Validity of 13 Claims of Patent 2,133,642

It is not disputed that when Pierce invented the oscillator he also invented a number of subsidiary electrical systems and endeavored to obtain a single patent but subsequently elected to accept separate patents.

The important characteristic of the oscillator was that with the aid of a piezoelectric crystal having only two electrodes, it was not necessary to rely upon mechanical feedback through a four-electrode crystal to obtain oscillations of a very high frequency such as are needed in radio transmission, and this was accomplished with the assurance that the oscillator will not oscillate except at that specific high frequency.

Since the validity of Patent 1,789,496 is not contested, the question simply posed requires a determination as to whether Patent No. 2,133,642 contains the same elements as Patent No. 1,789,496, and if this question is answered in the affirmative, the legal thesis of double patenting would apply which would make Patent No. 1,789,496 a predicate for the double patenting of No. 2,133,642.

Why do Claims 51, 52, 54, 55, 56 and 61 to 68, inclusive, of Patent 2,133,642 involve or relate to a scientific creation in the art which is not a distinct and separate invention from Patent No. 1,789,496?

It would be a waste of writer's ink to spell out and itemize the many marked similarities between the claims, uses and advantages that are set forth in the respective patents. A reference to each patent shows that Patent No. 2,133,642 when evaluated and read with Patent No. 1,789,496 discloses no invention separate and distinct in this most important area of scientific development.

Appendix B

Decision of U. S. District Court, S. D. of Florida

Pierce in Patents Nos. 1,789,496 and 2,133,642 made only one distinctive contribution to the Progress of Science and Useful Arts.

Patent No. 1,789,496 contributed a device which stabilized the frequency of oscillations of an electric circuit. Without this device the patent would not have been granted. Pierce cannot extract this essential element and make it the basis of a subsequent patent, since the Pierce oscillator, the subject of Patent No. 2,133,642 rather than the production of a constant beat, is the essential distinguishing feature of Combination Patent 1,789,496.

Patent No. 2,133,642 relates to electrical systems in which a vacuum or radio tube circuit is caused to oscillate. The oscillations produced thereby result in alternating currents of electricity which, when the electric current is designed for transmitting purposes, flow in and out of an antenna thereby producing carrier waves.

It is important that the frequency of the oscillations of the electrical circuit remains substantially constant, especially when the oscillating circuit is used for radio broadcasting.

A constant transmitting frequency results in the clearer reception of the carrier waves by a receiver tuned to that particular transmitting frequency. Also by decreasing the danger of interference from unstable frequency transmitters, a constant transmitting frequency permits the assignment of a greater number of broadcasting stations.

The law does not permit a patentee to extract an essential element from a former patent without which the prior patent would not have been granted, and make said essential element the subject of a subsequent patent.

It is my considered judgment that plaintiff is not entitled to injunctive relief nor can a claim be supported on any factual or legal thesis against the defendant since the

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thirteen claims of Patent No. 2,133,642 (51, 52, 54, 55, 56 and 61 to 68, inclusive) are invalid for double patenting when read with the Claims of Patent No. 1,789,496.

In view of this conclusion, the Court does not reach the second question

Did the defendant infringe any or all of the thirteen claims of Patent 2,133,642 by manufacturing, using and selling electrical and electromechanical vibrator systems and apparatus including the Pierce oscillator?

An appropriate order is entered.

Order

And now, this 15 day of June, 1961, summary judgment is granted in favor of the defendant, Aeronautical Communications Equipment, Inc., and against the plaintiff, Helen Russell Pierce, Executrix of the Last Will and Testament of George Washington Pierce, Deceased, as to all claims of Patent No. 2,133,642, and Patents Nos. 2,133,643, 2,133,645, 2,133,646, 2,133,648 and 2,266,070 together with costs.

Motion for summary judgment of the plaintiff, Helen Russell Pierce, Executrix of the Last Will and Testament of George Washington Pierce, Deceased, against the defendant, Aeronautical Communications Equipment, Inc., is refused as to all claims of Patent Numbers 2,133,642, 2,133,643, 2,133,645, 2,133,646, 2,133,648 and 2,266,070.

On Motion for Modification

On June 15, 1961, after a most thorough evaluation, study and review of the exhibits, documents, affidavits and arguments of counsel, the Court entered its opinion and judgment in this protracted patent litigation.

The matter presently before the Court is plaintiff's motion for modification of said opinion and order and re-

Appendix B

Decision of U. S. District Court, S. D. of Florida

quested rehearing, Federal Rules of Civil Procedure, Rules 52(b) and 59(e), 28 U. S. C. A.

I am satisfied that no useful purpose could be served for a reconsideration to be given of the many involvements and intricacies which exist from both a factual and legal standpoint. Most reflected judgment was given by the Court as to the respective theses of the parties and the conclusions reached are amply and fully supported by the stipulation of facts, the exhibits, and records as to claims 51, 52, 54, 55 and 61 through 68 of patent 2,133,642. An appropriate order will therefore be entered in which the motion for modification of the Court's opinion and order and for rehearing will be refused as to the aforementioned claims of patent 2,133,642.

Upon a review of the complete transcript of hearing, I am in accord with the position of plaintiff that it was not intended to withdraw from the Court's consideration the validity of claims 5, 9, 16, 22 and 23 of patent 2,133,646.

In approaching said adjudication, I have again reviewed all of the records, documents, exhibits, stipulations of the parties, and testimony incorporated as part of the record of this proceeding and must reach the conclusion that the five claims of patent 2,133,646 are void or invalid for double patenting under patent 1,789,496 which was an expired patent. No useful purpose could be served by setting forth in detail the nature and the basis of the patent which is being discussed since, in my judgment, the validity has been most learnedly and thoroughly considered by other Courts whose conclusions I am impelled to follow. The invalidity of the patent on the thesis of double patenting is therefore adjudicated on the basis of the following authorities: D. C. Mass., 159 F. Supp. 943; 1 Cir., 280 F. 2d 278; and D. C. Del., 178 F. Supp. 84. (It is noteworthy, concerning the adjudication entered by the United States Court for the District of Delaware that an appeal was perfected

from the decision of the trial judge to the United States Court of Appeals for the Third Judicial Circuit, during the pendency of which and before a determination was rendered, the plaintiff withdrew from the consideration of said Court the validity of all claims relative to patent 2,133,646.

Appropriate orders are entered.

Order

And now, this 11 day of August, 1961, on motion of plaintiff for modification of the Court's opinion and order entered June 15, 1961, under the provisions of Rules 52(b) and 59(e), Federal Rules of Civil Procedure, and for re-hearing as to claims 51, 52, 54, 55, and 61 through 68 of patent 2,133,642 is refused.

Order of summary judgment in behalf of the defendant as expressed in the Court's opinion of June 15, 1961 is reaffirmed. Order denying summary judgment in behalf of plaintiff against defendant as to claims 51, 52, 54, 55, and 61 through 68 of patent 2,133,642 is reaffirmed.

It is further ordered that claims 5, 9, 16, 22 and 23 of patent 2,133,646 are ripe for consideration and the claims of said patent are hereby decreed void for double patenting. Defendant's motion for summary judgment as to claims 5, 9, 16, 22 and 23 of patent 2,133,646 is hereby granted. Plaintiff's motion for summary judgment against the defendant as to claims 5, 9, 16, 22 and 23 of patent 2,133,646 is refused.

APPENDIX C

Summary (and Final) Judgment in Favor of Defendant

(Filed May 2, 1957)

UNITED STATES DISTRICT COURT

SOUTHERN DISTRICT OF FLORIDA—MIAMI DIVISION

No. 5638-M—Civil

HELEN RUSSELL PIERCE, Executrix of the Last Will and Testament of GEORGE WASHINGTON PIERCE, Deceased,

Plaintiff,

vs.

AERONAUTICAL COMMUNICATIONS EQUIPMENT, INC.,

Defendant.

This cause having come on to be heard on March 28, 1957, upon the Defendant's Motion For Summary Judgment filed August 20, 1956, and the Court, having heard argument of counsel and having considered the matters of record herein together with the memoranda of law submitted by counsel, is of the opinion that there is no genuine issue as to any material fact and the Defendant is entitled to summary (and final) judgment as a matter of law based on the reasoning in the cases of American Communications Co., Inc., v. Pierce, 208 F. 2d 763 (1st Cir. 1953), and Pierce v. Hewlett-Packard Co., 220 F. 2d 531 (1st Cir. 1955), it is, therefore,

Appendix C

Summary (and Final) Judgment in Favor of Defendant

ORDERED AND ADJUDGED that Summary (and Final) Judgment be and the same is hereby entered in favor of the Defendant, Aeronautical Communications Equipment, Inc., and against the Plaintiff, Helen Pierce, Executrix of the Last Will and Testament of George Washington Pierce, Deceased, and it is,

FURTHER ORDERED AND ADJUDGED that the costs incurred by the Defendant herein be and the same are hereby taxed against the Plaintiff, for which sum let execution issue.

DONE AND ORDERED in chambers at Miami, Florida, this 2nd day of May, 1957.

EMETT C. CHOATE
United States District Judge

I certify the foregoing to be a true and correct copy of the original.

(SEAL)

JULIAN A. BLAKE, Clerk
United States District Court
Southern District of Florida

By s (s) PATRICIA L. GABEL
Deputy Clerk

APPENDIX D

Decision of U. S. Court of Appeals, Fifth Circuit

(Decided May 12, 1958)

UNITED STATES COURT OF APPEALS

FIFTH CIRCUIT

No. 16830

Helen Russell PIERCE, Executrix of the Last Will and Testament of George Washington Pierce, Deceased,
Appellant,

v.

AERONAUTICAL COMMUNICATIONS EQUIPMENT, Inc.,
Appellee.

May 12, 1958.

Before RIVES, TUTTLE and JONES, Circuit Judges.

TUTTLE, Circuit Judge.

This is an appeal from an order of the United States District Court for the Southern District of Florida granting defendant's motion for summary judgment. The defendant is charged with infringing five patents issued to the former, now deceased, plaintiff, George Washington Pierce. The five patents in the suit comprise Nos. 2,133,642, 2,133,643, 2,133,645, 2,133,646, and 2,133,648, all issued on October 18, 1938.[1] It is alleged that the defendant a

1. The complaint also alleged infringement of a sixth patent, No. 2,266,070, but plaintiff withdrew it at an earlier stage in the litigation.

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Decision of U. S. Court of Appeals, Fifth Circuit

Florida corporation, is infringing plaintiff's exclusive rights under these patents by manufacturing, using and selling electrical and electromechanical vibrator systems and apparatus, including the Pierce oscillator. The summary judgment has the effect of ruling that all of the patents in issue are invalid.

The primary, but not the sole, importance of the patents involved is in the field of radio broadcasting where a need had existed for controlling the frequency of oscillating electrical circuits. Radio communication is transmitted by carrier waves which are generated from the transmitter by an alternating current of electricity flowing in and out of an antenna, composed of wires suspended in the air. Radio waves are produced when the current oscillates at a high frequency. Since communication between a sender and a receiver is possible only when both are tuned to the same frequency, it is highly desirable that the frequency of the waves sent out from a transmitter remain constant.

The problem of attaining constant frequency had existed prior to 1912 when deForest discovered that the thermionic vacuum tube or triode could be used to generate electric oscillations. This invention provided a feasible method, and since 1912 many experts in the field searched for improved means of controlling the frequency of electric systems. The principal fault with the deForest tube was that after the circuit had been in operation a while the elements in the circuit became heated and an undesirable amount of variation in the frequency resulted.

It was finally through the use of piezoelectric crystals that the solution came. These crystals were first noted in 1880 by Jacques and Pierre Curie. Because of their component substances, direct current when applied to them will cause the surfaces of the crystal to contract or expand. When mechanical forces are applied to contract or expand

the crystal, electrical potentials of opposite sign are built up on the opposing surfaces of the crystal. Little had been accomplished in using the piezoelectric crystals in the radio field until Professor Walter G. Cady, of Wesleyan University began experimenting with the possibilities, and his work eventually attracted the attention of Pierce.

Professor Pierce discovered a means whereby the circuit could oscillate without employing any inductive coils or condensers and this could be accomplished at a remarkably constant frequency. In the Pierce oscillator, as it has come to be called in the field, a piezoelectric crystal is positioned in the input circuit, between the cathode and the grid or control electrode, or between the grid or control electrode and the anode. In the first named system the tunable resonant output circuit, consisting of the inductance coil and the condenser, is tuned to a higher frequency than the natural frequency of the crystal. Then when the system is in operation it will produce oscillations at a constant frequency determined by the natural frequency of the crystal. An important characteristic of the Pierce oscillator is that with the aid of a piezoelectric crystal having only two electrodes, it is not necessary to rely upon mechanical feed-back through a four-electrode crystal to obtain oscillations of very high frequencies such as are needed in radio transmission, and this is accomplished with the assurance that the oscillator will not oscillate except at that specific high frequency.

The Pierce oscillator is in wide use throughout the world through the licensing agreements granted by Professor Pierce, and it is acknowledged that Pierce has made a significant contribution to the field of electrical circuits and radio transmission.

At the time of inventing the Pierce oscillator, Pierce invented a number of subsidiary electrical systems for which, by application of February 25, 1924, he endeavored to obtain a single patent covering them all. Since this ap-

plication included not only general claims for the use of a piezoelectric crystal to control the frequency of an oscillating system but also specific claims for the combination of a radio transmitter and receiver in which such crystals could be used, the Patent Office held that more than one invention was described in the application and ordered a division. In compliance with this order Pierce filed a *number of additional* applications and several of the resulting patents are involved in this suit. One of the additional applications matured, however, on January 20, 1931, into patent No. 1,789,496, and this patent expired in 1948, before the defendant began the infringement acts complained of in this suit.

Patent No. 1,789,496, consisting of three claims, is for a radio transmitting and receiving system in combination, having a means of keeping the oscillations of both the transmitter and receiver at the same constant frequency. Claim 1 specifically mentions the use of a piezoelectric body for controlling the frequency of these oscillations and that would seem to allow the piezoelectric-crystal-controlled oscillators shown in the Cady patent No. 1,472,583 to be used as an element in the combined transmitting and receiving system. Claim 2 specifies the use of an electro-mechanical vibrator having two electric terminals in a single vacuum tube circuit, which circuit oscillates at a frequency widely independent of the other elements in the circuit. It thus apparently specifies the Pierce oscillator. Claim 3 is much broader in that it calls for any kind of prior art electro-mechanical vibrator to control the frequency.

Action on Pierce's other applications, which resulted from the order for a division was delayed because of requests for a fuller explanation of the properties of piezoelectric crystals and the failure to pay on time the required final fee. On April 20, 1939, the Patent Office issued a patent to John M. Miller covering claims 51, 52, 54, 55, 56 and

61 to 68 inclusive of Pierce's now patent No. 2,133,642. Litigation resulted in the holding that Pierce and not Miller was the inventor of the Pierce oscillator represented by the above claims. Miller v. National Broadcasting Company, Inc., 3 Cir., 79 F. 2d 657; Miller v. Pierce, 97 F. 2d 141, 25 C. C. P. A., Patents, 1195. Thereafter, on October 18, 1938, the Pierce patent, No. 2,133,642, and the other four patents involved in this suit were issued.

After th expiration in 1948 of the protection provided by Patent No. 1,789,496 various business concerns began to produce electrical vibrator systems, which Pierce believed infringed his six patents, which had not, by that time expired. He entered nine suits in several different circuits against various defendants.[2]

In the instant suit the plaintiff moved for a preliminary injunction to restrain the defendant from infringing the thirteen claims of patent No. 2,133,642 which were in issue in Pierce's litigation with Miller. That motion was denied and the denial was affirmed by this Court on the g ounds that there was no showing of irreparable injury c abuse of discretion. 223 F. 2d 410.

Since the District Court in the issue now before us based its summary judgment upon the "reasoning" of two First Circuit Court of Appeals cases instituted by the plaintiff against others than the present defendant, it becomes necessary at the outset to consider those opinions. In American Communications Co. v. Pierce, 1 Cir., 208 F. 2d 763, both parties moved for summary judgment only on claims 51, 52, 54, 55, 56 and 61 to 68, inclusive, of the basic patent, No. 2,133,642. The district court 111 F. Supp. 181, holding that the claims were valid and infringed, granted plaintiff's motion and denied defendant's motion. The Court of Appeals reversed, holding that generic patent No. 2,133,642 for an electrical system relating particularly to

2. The eighth of those suits was Pierce v. Allen B. Du Mont Laboratories, D. C. Del., 156 F. Supp. 237. Footnote 1 therein lists the nine cases.

the use of a piezoelectric crystal for producing at a constant frequency the oscillation of such system, when read specifically on the combined transmitting and receiving systems discloses no invention distinct and separate from that of patent No. 1,789,496 and that it would not extend the plaintiff's monopoly under the mantle of patent No. 2,133,642. The Court reasoned that neither claim 1 nor claim 3 of patent No. 1,789,496 revealed any distinctive contribution to the art of frequency stabilization or radio systems; and when analyzing claim 2 with a typical claim of patent No. 2,133,642, claim 67, clause by clause, it concluded that the only significant difference indicated in the claims is the use to which the piezoelectric crystal may be put. Claim 2 of patent No. 1,789,496 narrows the operation of the crystal to the combined transmitting and receiving system whereas claim 67 of patent No. 2,133,642 more broadly states its use in any generating system. But as the radio system described by Pierce was held not to be novel in and of itself, the only inventions were the position and the method in which the two-electrode piezoelectric crystal was used in the combination.

In the other case, the district court in Pierce v. Hewlett-Packard Company, 125 F. Supp. 329, granted defendant's motion for summary judgment, declaring the above claims of patent No. 2,133,642 invalid. The Court of Appeals affirmed on the authority of the American Communications Co. case to the effect that there was double patenting in that the plaintiff's patents Nos. 1,789,496 and 2,133,642 made only one distinctive contribution, which was the novel use of the two electrode piezoelectric crystal in a single vacuum tube circuit. 1 Cir., 220 F. 2d 531.

(1) As the present appeal involves all five of Pierce's patents it is apparent that there is more in issue in this suit than in the First Circuit cases and in the prior appeal in this case. The claims of patent No. 2,133,642, other than

the thirteen litigated by the Court of Appeals of the First Circuit and the claims of the remaining four patents were not in issue or even considered by the First Circuit[3] in the cases upon which the district court in this case based its holdings. As the plaintiff is entitled to a considered opinion by the district court, she should be given an opportunity to present evidence including expert testimony, documents and exhibits to prove that the nonlitigated claims involve improvements or entirely different inventions from those involved in the thirteen claims of patent No. 2,133,642. This is entirely apart from the question of correctness of the trial court's judgment as to these thirteen claims.

(2) It does appear that plaintiff, in order to secure a ruling that could have decided the validity issue in her favor, selected for the prior suits and the preliminary injunction motion in this suit certain claims of patent No. 2,133,642, and termed it the "basic patent," but this decision should not preclude her from having the courts pass upon the validity of the other patents. Since there is a different defendant in this suit no issue of res judicata or collateral estoppel can arise to bind the plaintiff by any holding or stipulation in the prior suits.

(3-5) We ought not dismiss too quickly the fact that the Patent Office Examiner ordered a division of plaintiff's original application on the ground that there were separate and distinct inventions and that six patents were granted from plaintiff's applications. As was stated in In re Cady,

3. It is noted that upon remand of the American Communications Company case, Judge Ford, in an unpublished opinion, Civil Action No. 51,526-F, January 31, 1958, considered the other claims and patents and held that all but patent No. 2,133,643 were void for double patenting. He, therefore, granted summary judgment for the defendant in respect to all patents except that one. The issue as to that one remains to be tried. This opinion could not have been a basis for the district court's decision which was entered May 2, 1957.

Appendix D

Decision of U. S. Court of Appeals, Fifth Circuit

77 F. 2d 106, 109, 22 C. C. P. A., Patents, 1130, decisions of the examiner "should not be lightly overruled." The burden of establishing invalidity of a patent rests upon the party asserting it and that burden is heavy. 35 U. S. C. A. 282; Mumm v. Jacob E. Decker & Sons, 301 U. S. 168, 57 S. Ct. 675, 81 L. Ed. 983. From the status of the record regarding these patents it does not appear that these patents received the consideration from the court to which they were entitled; and the case was not, therefore, ripe for summary judgment.

In regard to claims 51, 52, 54, 55, 56 and 61 to 68 inclusive of patent No. 2,133,642 we find that the opinion of the American Communications case and the opinion of the Hewlett Packard case, even if valid concerning double patenting, when placed together, do not necessarily preclude plaintiff's success in this case. It is still open to the plaintiff to contend and prove that the 1,789,496 patent was invalid for want of invention and that the 2,133,642 patent is not, therefore, void for double patenting. See O'Reilly v. Morse, 15 How. 62, 14 L. Ed. 601; Thomson-Houston Electric Co. v. Ohio Brass Co., 6 Cir., 80 F. 712. If the combination patent, No. 1,789,496 was not a valid invention, it was void *ab initio*; and having no existence there could be no monopoly relating to it and it could not be used as a predicate for double patenting. Since this case must be remanded for trial upon the merits of the above patents, plaintiff in all fairness should be allowed an opportunity to present this proof.

4 Although the Patent Act of 1952, especially section 121 of Title 35 was not in effect when the Patent Office ordered the division of this case, it does embody the policy of protecting the patentee in certain respects, including the benefit of the earlier filing date, when a division is ordered by the Office. The report from the House of Representatives Committee on the Judiciary, H. R. Rep. No. 1923, 82nd Congress, 2nd Session, 1952 states that "neither of the resulting patents can be held invalid over the other merely because of their being divided in several patents."

6) In explaining its American Communications decision, the First Circuit Court of Appeals said in Hewlett-Packard that "the plaintiff in patents Nos. 1,789,496 and 2,133,642 made only one distinctive contribution." Further it stated:

> "The plaintiff received patent No. 1,789,496 only because of his contribution of a device which stabilized the frequency of oscillations of an electric circuit. Without this device the patent would not have been granted. The plaintiff cannot extract this essential element and make it the subject of a subsequent patent. Palmer Pneumatic Tire Co. v. Lozier, supra, 90 F. [732] at page 744, see Application of Horneman, 1952, 194 F. 2d 108, 39 C. C. P. A., Patents, 809. The Pierce oscillator, the subject of patent No. 2,133,642 rather than the production of a constant beat, is the essential distinguishing feature of combination patent No. 1,789,496. See Application of Coleman, 1951, 189 F. 2d 976, 38 C. C. P. A., Patents, 1156." [220 F. 2d 532.]

This language suggests that patent No. 1,789,496 was not valid at all in that it was issued for a combination radio transmitting and receiving system with claims both using and not using Pierce oscillators. It can be argued that if the combination, the idea of the patent, lacks invention, the entire patent is invalid. In the situation, as in patent No. 1,789,496, in which the patentee relies upon the combination as a whole, rather than one element of it, the court should judge the combination itself as a whole. See Rieke Metal Products Corp. v. Barrel Fitting & Seal Corp., 7 Cir., 100 F. 2d 259; 40 Am. Jur., Patents §163. Where the patent is for a combination and no claim is made specifically for any one of the elements, it is conclusively presumed that the elements are old in the art or are not patentable. Richards v. Chase Elevator Co., 159 U. S. 477,

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16 S. Ct. 53, 40 L. Ed. 225; Harris v. Ladd, 8 Cir., 34 F. 2d 761; City of St. Louis v. Prendergast, 8 Cir., 29 F. 2d 188. The district court, therefore, must ascertain first whether claims No. 1 and No. 3 are too broad, and if the decision is that they describe radio systems already in the public domain, then it must proceed to determine whether the Pierce oscillator is claimed sufficiently in claim No. 2 to provide the combination with an element of novelty. If upon this analysis, invention is found lacking, patent No. 1,789,496 is invalid and there can be no double patenting.

(7). Even if the First Circuit cases have analyzed the situation correctly, they do not proceed to the point of considering the position of a patentee who has a patent on a combination invention which includes in it a patentable element. The plaintiff in this case may be able to prove that the Pierce oscillator itself is not sufficiently described in claim 2 of patent No. 1,789,496 to provide Pierce with sufficient protection. If someone had used the Pierce oscillator in a system other than the radio system described in No. 1,789,496, the plaintiff would have had difficulties, perhaps insurmountable, in proving that he was afforded protection under No. 1,789,496. A patent on a combination is a patent on the functioning whole, not on the separate parts and the fact that an unpatented element of a combination may distinguish the invention does not draw to it the privileges of a patent. Mercoid Corporation v. Mid-Continent Investment Co., 320 U. S. 661, 64 S. Ct. 268, 88 L. Ed. 376; Mercoid Corporation v. Minneapolis-Honeywell Regulator Co., 320 U. S. 680, 64 S. Ct. 278, 88 L. Ed. 396; Rowell v. Lindsay, 113 U. S. 97, 5 S. Ct. 507, 28 L. Ed. 906.

The reasoning of the above First Circuit opinions is, moreover, opposed to the basis of the division order and places the inventor in a perplexing dilemma. He must divide his claims into separate applications for separate pat-

ents to comply with the Patent Office's requirements, but when he does this he faces the prospect of losing part of his protection, if, as in this case, the patents are issued at different times, and the double patenting argument is used against him. If, as appears to be undisputed, the plaintiff did make a significant contribution with the Pierce oscillator, he is entitled to a patent on it alone to prevent its use without his consent in any combination and for the full 17 years. If the oscillator is not specifically claimed as such in patent No. 1,789,496 that patent should stand or fall as a combination patent and have no bearing on the oscillator patent No. 2,133,642; otherwise, by obeying the Patent Office's order the plaintiff is denied a portion of the protection to which he is entitled.

Since it was the Patent Office which required the division that led to the two separate patents, plaintiff does not come under the rule of Palmer Pneumatic Tire Co. v. Lozier, 6 Cir., 90 F. 732, prohibiting one from extracting an essential element of his invention from a former patent without which that patent would not have been granted and taking it for the subject of a new patent. Plaintiff originally had presented all of his claims in 1924 and because of the separation ruling and the litigation with Miller he was not awarded a final patent on the oscillator itself until 1938. He is not then in the position of one who tries to extend his coverage by taking the element from the combination for a later and separate patent. Plaintiff should now be allowed to prove that the oscillator is not specifically claimed in patent No. 1,789,496, and that at most it was only protected by that patent to the extent it was used in the combination described therein.

The judgment of the District Court is reversed and the case is remanded for further proceedings not inconsistent with this opinion.

5. This is one of the evils to which section 121, Title 35 of the Patent Act of 1952 is directed, see footnote 4 above.

APPENDIX E

Decision of U. S. Court of Appeals, First Circuit

(Decided December 18, 1953)

No. 4757

UNITED STATES COURT OF APPEALS

FIRST CIRCUIT

AMERICAN COMMUNICATIONS CO., INC.

v.

PIERCE

Dec. 18, 1953

Rehearing Denied Jan. 15, 1954

Patent infringement action.

Before MAGRUDER, Chief Judge, and
WOODBURY and HARTIGAN, Circuit Judges.

HARTIGAN, Circuit Judge.

This is an appeal from an order of the United States District Court for the District of Massachusetts docketed April 23, 1953, granting plaintiff's motion for partial summary judgment. In his complaint plaintiff alleged infringement of seven patents[1] owned by him, but both parties moved for partial summary judgment under the provisions of Rule 56, F. R. C. P., 28 U. S. C. A. only on claims 51, 52

1. No. 2,133,642, No. 2,133,643, No. 2,133,644, No. 2,133,645, No. 2,133,646, No. 2,133,648 and No. 2,266,070.

54, 55, 56 and 61 to 68 inclusive of the basic patent No. 2,133,642. The district court heard the matter on affidavits, exhibits and documents submitted by both parties. It held that said claims were valid and infringed and granted the plaintiff's motion and denied the defendant's motion.

The application for the basic patent No. 2,133,642 was filed in the Patent Office on February 25, 1924 but because of a subsequent suit [2] brought against two subsidiaries of one of plaintiff's licensees, a Patent Office Interference [3] with one Miller who claimed the same invention as the plaintiff, and divisional rulings by the Patent Office, the basic patent No. 2,133,642 was not issued until October 18, 1938.

Defendant, American Communications Company, Inc., a Massachusetts corporation, first leased in November, 1949 from Federal Telephone & Radio Corporation certain radio transmitting and receiving equipment. The defendant's use of this equipment in the conduct of its business is alleged to infringe patent No. 2,133,642. Federal Telephone & Radio Corporation, named as a defendant, is a Delaware corporation doing business in New Jersey and is the manufacturer and lessor of the accused radio equipment. It has not been served in Massachusetts and has declined to appear voluntarily in this action.

Patent No. 2,133,642, titled "Electrical System", relates to electrical systems in which a vacuum or radio tube circuit is caused to oscillate. The oscillations produced thereby result in alternating currents of electricity which, when the electrical circuit is designed for transmitting purposes, flow in and out of an antenna thereby producing "carrier"

2. Miller v. National Broadcasting Co., D. C. Del. 1934, 6 F. Supp. 47, affirmed 3 Cir., 1934, 79 F. 2d 657, rehearing denied Oct. 28, 1935.

3. Miller v. Pierce, 1938, 97 F. 2d 141, 25 C. C. P. A., Patents, 1195.

waves. It is important that the frequency of the oscillations of the electrical circuit remains substantially constant. This is particularly true when the oscillating circuit is used for radio broadcasting which the district court found to be the primary importance of the patent in suit. A constant transmitting frequency results in the clearer reception of the carrier waves by a receiver "tuned" to that particular transmitting frequency. Also by decreasing the danger of interference from unstable frequency transmitters, a constant transmitting frequency permits the assignment of a greater number of broadcasting stations. The plaintiff's patent No. 2,133,642 claims a method whereby the frequency of oscillating circuits is rendered constant to an extent not obtainable in the prior art. He asserts that when a two electrode crystal, with the piezo-electrical properties of generating mechanical vibrations under vibratory electrical stimulus and conversely of developing electrical potentials as a result of its mechanical vibrations, was inserted into a non-oscillating simple vacuum tube circuit in place of the prior art "tunable" coils and condensers, the piezo-electric crystal both produced and sustained the frequency of the oscillations of the circuit at a substantially constant rate, widely independent of the electrical constants of the system.

The defendant in the lower court relied on the defenses of invalidity, non-infringement, double patenting and laches. In holding for the plaintiff the court found no merit in these defenses. In its oral argument before us the defendant stated its willingness to accept the lower court's statement of facts and contended that in view of such facts there is a clear case of double patenting in this action. In that portion of its opinion dealing with the question of double patenting the district court stated: "The original Pierce patent application Serial No. 695,064 was filed on February 25, 1924. It included not only general claims for the use of a piezo-electric crystal to control the frequency

of an oscillating system but also (claims 53, 54 and 57) specific claims for the combination of a radio transmitter and receiver in which such crystals could be used. The Patent Office, holding that more than one invention was described in the application, ordered a division. In compliance with this order Pierce, on January 18, 1928, filed several divisional applications. On one of these, Ser. No. 247469, patent No. 1,789,496 was issued on January 20, 1931. * * * This divisional patent covered combined transmitting and receiving systems and expired on January 20, 1948, almost two years before the defendant first leased the accused radio equipment from Federal Telephone & Radio Corporation.

In plaintiff's expired patent No. 1,789,496 three claims are specific.[4] Neither claim 1 nor claim 3 reveal the plain-

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4. 1. A transmitting and receiving system having, in combination, means for transmitting signal waves, means for receiving the signal waves, a local oscillating system comprising an amplifying relay having an inherent regenerative coupling, a source of energy, a piezo-electric body, and means connecting the relay, the source and the body together, the connecting means being such that the local system can not oscillate through the inherent regenerative coupling when the body is disconnected from the system, whereby the frequency of the waves of the local oscillating system is maintaingl substantially constant, and means for combining the received waves with the local waves.

2. A transmitting and receiving system having, in combination, means for transmitting signal waves, means for receiving the signal waves, each of the said means comprising a source of electric energy, a tube having a plurality of electrodes, an electro-mechanical vibrator having two electric terminals respectively connected with two of the electrodes, means substantially nonperiodically connecting the source, the tube, and the vibrator together to maintain the vibrator in vibration and the system in oscillation with a frequency widely independent of the electrical constants of the system and determined by a mode of mechanical vibration of the vibrator, the electrical parameters of the system being such that the system will not oscillate in the absence of the vibrator, the terminals being adapted to act conjointly both

Appendix E

Decision of U. S. Court of Appeals, First Circuit

tiff's distinctive contribution to the art of frequency stabilization. The plaintiff states in his brief that the prior art piezo-electric-crystal-controlled oscillators shown in the Cady patent No. 1,472,583 may be used as an element in the combined transmitting and receiving system specified in claim 1. Claim 3 is even broader, covering any kind of prior art electro-mechanical vibrator. Claim 2, however, sets forth the plaintiff's distinctive contribution to the art of frequency stabilization in combined transmitting and receiving systems. By specifying the use of a two-electrode electro-mechanical vibrator in a single vacuum tube circuit, which circuit oscillates at a frequency widely independent of the other elements in the circuit and only upon the insertion of the vibrator, the plaintiff claimed a significant improvement over the prior art frequency controlled oscillating circuits.

The defendant asserts, and we do not understand the plaintiff to deny, that claim 2 of reissue patent No. 1,789,496 reads upon the accused structures. The circuit diagrams of the defendant's accused receivers shown in the "Instruction Books for Radio Equipment FT-[illegible]A and FT-145-10A", simplified in plaintiff's exhibit XVIII B, are, for the purposes of frequency stabilization, substan-

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for electric stimulation and electric response to affect the oscillations of the system, and means for evidencing beats.

3. A transmitting-and-receiving system having, in combination, a transmitting system for transmitting electric waves, an electro-mechanical vibrator connected with the system for maintaining the frequency of the transmitting system substantially constant, the connections being such as to prevent the operation of the transmitting system at other than the said substantially constant frequency, a receiving system for receiving the electric waves, the receiving system being traversed by local oscillations, and an electromechanical vibrator connected with the receiving system for maintaining the frequency of the local oscillations substantially constant, the connections of the second-named electromechanical vibrator with the receiving system being such as to prevent the local oscillations at other than the second-named substantially constant frequency.

tially the same as the receiver circuit diagrams of Figs. 1 and 3 of patent No. 1,789,496. The three-electrode vacuum tube marked V65 in plaintiff's exhibit XVIII-B corresponds to the three-electrode vacuum tubes 124 of Figs. 1 and 3 of patent No. 1,789,496. The piezo-electric crystal Y1 of exhibit XVIII-B corresponds to crystal 2 of Figs. 1 and 3 of patent No. 1,789,496. The condenser C27 in exhibit XVIII-B is merely a conventional output path for the oscillations generated by the circuit and does not affect the operation of the oscillator circuit itself. Condenser C66 and inductance L65 of exhibit XVIII-B represent a parallel tuned resonant circuit in the output circuit of the oscillator and correspond to the inductance coil 40 of Fig. 3 of patent No. 1,789,496. Although there is no condenser shown parallel to the inductance coil 40 of Fig. 3, nevertheless, as is well-known in the art, inherent capacitance is present across the inductance coil 40. The source of electrical energy designated B+ in exhibit XVIII-B produces upon the plate of vacuum tube V65 a positive voltage potential and corresponds to the battery 32 of Figs. 1 and 3. The telephone receiver 42 and the bypass condenser 44 in the plate circuit of Figs. 1 and 3, as the plaintiff states in patent No. 1,789,496 are optional and may be replaced by an inductance, or by the primary winding of a transformer, or by the input terminals of an amplifier, or may be wholly short-circuited. The condenser C69 in the grid-cathode circuit of exhibit XVIII-B is not, as plaintiff's expert Professor Bowles states, essential to the generation of oscillations in the oscillator circuit. The only significant diagrammatic variation in these circuits seems to be in the position of the piezo-electric crystal in the receiver of Fig. 1 of patent No. 1,789,496. The crystal is there placed in the plate-cathode or output circuit, whereas in the other circuit diagrams the crystal is positioned in the grid-cathode or input circuit. However, plaintiff states in his patent No. 1,789,496, p. 1, lines 85-94 inclusive:

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> "The electromechanical vibrator, shown as a piezo-electric body 2, is differently disposed in the different diagrams, so as to illustrate a few of the many different ways in which the vibrator may be employed. It is to be understood, however, that the vibrator disposition, in a particular diagram, is not specific to that diagram, but that the vibrator may be similarly disposed in the other diagrams. * * * "

Also by a similar comparison of the transmitting circuits of radio equipments FT-149-30AZ and FT-145-10A, simplified in plaintiff's exhibits XIX-B and XX-B respectively, with the transmitting circuit of Fig. 1 of patent No. 1,789,496, it will be seen that the circuits are, in all material aspects, substantially identical.

(1) Plaintiff contends, however, that claims 51, 52, 54, 55, 56 and 61 to 68 inclusive of the unexpired patent No. 2,133,642 also read upon the accused structures. He must show, therefore, that, in relation to the accused structures, patent No. 2,133,642 was granted for a distinct and separate invention from that of expired patent No. 1,789,496, for, as was stated in Miller v. Eagle Manufacturing Co., 1893, 151 U. S. 186, 198, 14 S. Ct. 310, 315, 38 L. Ed. 121:

> "The result of the foregoing and other authorities is that no patent can issue for an invention actually covered by a former patent, especially to the same patentee, although the terms of the claims may differ; that the second patent, although containing a broader claim, more generical in its character than the specific claims contained in the prior patent, is also void; but that where the second patent covers matter described in the prior patent, essentially distinct and separable from the invention covered thereby and claims made thereunder, its validity may be sustained.

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> "In the last class of cases it must distinctly appear that the invention covered by the later patent was a separate invention, distinctly different and independent from that covered by the first patent; in other words, it must be something substantially different from that comprehended in the first patent. It must consist in something more than a mere distinction of the breadth or scope of the claims of each patent. If the case comes within the first or second of the above classes, the second patent is absolutely void. * * *"

Assuming that claims 51, 52, 54, 55, 56 and 61 to 68 inclusive of patent No. 2,133,642 read upon the accused structures, we do not understand how, with respect to the accused structures, these claims of patent No. 2,133,642 may be said to be a distinct and separate invention from that of claim 2 of expired patent No. 1,789,496.

Plaintiff admits that the transmitter portion of the combined transmitting and receiving system of Fig. 1 of patent No. 1,789,496 is substantially the same as the transmitter illustrated by Fig. 7 of the plaintiff's basic patent No. 2,133,642 and that the receiver portion of Fig. 1 is the same as the receiver illustrated by Fig. 8 of the plaintiff's patent No. 2,133,642. Plaintiff further admits that the modified transmitting system shown in Fig. 2 of the combination patent No. 1,789,496 is substantially a reproduction of Fig. 9 of the plaintiff's patent No. 2,133,642. To indicate the similarity between claim 2 of patent No. 1,789,496 and the allegedly infringed claims of patent No. 2,133,642 we have compared in the margin[5] the elements of claim 2 of patent

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5. Claim 2 of expired patent No. 1,789,496

A transmitting and receiving system having, in combination, means for transmitting signal

Claim 67 of basic patent No. 2,133,642

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No. 1,789,496 with a representative claim such as claim 67 of patent No. 2,133,462. Claim 2 of patent No. 1,789,496 states the use of an electro-mechanical vibrator, but the succeeding elements of the claim reveal that such a vibrator

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waves, means for receiving the signal waves, each of said means comprising a source of electric energy,

A generating system

of constant frequency oscillations

a tube having a plurality of electrodes,

comprising a vacuum tube,

an electro-mechanical vibrator

a piezo-electrical element of hard, durable material

having two electric terminals respectively connected with two of the electrodes,

provided with a single pair of operative electrodes in circuit with said tube,

means substantially non-periodically connecting the source, the tube, and the vibrator together

and a resonant circuit in the output of said tube carrying oscillating currents

to maintain the vibrator in vibration and the system in oscillation with a frequency widely independent of the electrical constants of the system and determined by a mode of mechanical vibration of the vibrator,

having a frequency determined at all times by a natural period of mechanical vibration of said piezo-electric element,

the electrical parameters of the system being such that the system will not oscillate in the absence of the vibrator,

said piezo-electric element constituting an essential element in the system for the generation of oscillations.

the terminals being adapted to act conjointly both for electric stimulation and electric response to effect the oscillation of the system, and means for evidencing beats.

corresponds with the piezo-electrical element specified in claim 67 of patent No. 2,133,642. It seems to us that the only significant difference indicated in the respective claims of the two patents is the use to which the piezo-electrical body may be put. Claim 2 of patent No. 1,789,496 narrows the operation of the piezo-electric crystal to a combined transmitting and receiving system. Claim 67 of patent No. 2,133,642 more broadly states its use in "a generating system." But when the generic "generating system" of claim 67 is read so as to apply to the accused combination transmitting and receiving structures in suit, then patent No. 2,133,642 claims nothing that is separate and distinct from claim 2 of patent No. 1,789,496.

The plaintiff claimed in patent No. 1,789,496 an improved means for frequency stabilization in combined transmitting and receiving systems. He did not claim to be the first to produce a combined transmitting and receiving system as such. It was the use of the plaintiff's two-electrode piezo-electric crystal in the combination, and not the combination itself, which constituted the "essential distinguishing feature" of patent No. 1,789,496. Application of Coleman, 1951, 189 F. 2d 976, 979, 38 C. C. P. A., Patents, 1156. Thus, what we said in Otis Elevator Co. v. Portland Co., 1 Cir., 1903, 127 F. 557, 562, applies with equal force here: "* * * Bassett did not, in his first patent, reserve what he now terms his generic invention. By patenting a specific machine as an embodiment of his generic invention, and not because of any distinct invention involved in specific and patentable features, he patented the subject-matter of the claims of the patent in suit. * * *"

Plaintiff attempts to find a distinction between the two patents with relation to the accused structures in the specification of patent No. 1,789,496 which states: "The superposed frequency may also be used to supply a carrier wave in a radio telephone system where the system operates by

suppressed carriers," and from the affidavit of plaintiff's expert, Professor Bowles, who states: "In one system of radio transmission, a much more efficient transmission can be achieved if one of the components of the transmitted wave, known as the 'carrier' can be 'suppressed', that is, not transmitted. This leaves its power to be applied to increase the energy of that part of the signal which is transmitted. The reception of such a signal requires that oscillations of exactly this carrier frequency be supplied independently at the receiver. If the said frequency is not precisely right the signal is garbled. The Pierce patent 1,789,496 solves his problem." Plaintiff argues that this problem could not be solved by merely controlling a transmitter alone or a receiver alone as claimed in patent No. 2,133,642. But plaintiff in his brief admits this was only one "particular additional problem," and we believe its solution to be an incidental and auxiliary result to the solution of the main problem for which the plaintiff was granted patent No. 1,789,496 namely, improved frequency stabilization of oscillations in a combination transmitting and receiving system by the use of a two-electrode piezo-electric crystal in a single vacuum tube circuit.

(2) Plaintiff further attempts to distinguish the two patents on the grounds that under claim 1 of patent No. 1,789,496 the prior art piezo-electric crystal of Professor Cady, and under claim 3 any kind of electro-mechanical vibrator, may be used in the combined transmitting and receiving system. Even if such a construction of claims 1 and 3 of patent No. 1,789,496 is a correct one (which seems doubtful in view of the specifications, particularly pages 3 and 4 of the patent, and the diagrams none of which show anything that resembles a Cady oscillating circuit), nevertheless, the distinctive contribution of the plaintiff to the art of frequency stabilization in a combined transmitting and receiving system was embodied in claim 2 of patent No. 1,789,496. Cady's prior art circuits shown in Figs. 1, 3 and 4 of his patent No. 1,472,583, plaintiff admits, stabilized the

frequency of the oscillations of the circuit over a very narrow range of variation of the other electrical elements of the circuit and oscillated even upon removal of the piezo-electric crystal from the circuit. The oscillating circuit specified in claim 2 of patent No. 1,789,496, on the other hand, maintained a frequency widely independent of any variation in the other electrical elements of the circuit and only osgillated upon insertion of the piezo-electric crystal. Also Cady's circuit shown in Fig. 2 of his patent No. 1,472,583 required three vacuum tubes to produce and control oscillations and, plaintiff admits, was only an effective stabilizer at low frequencies because of the necessity of a piezo-electric crystal with four electrodes. The oscillating circuit specified in claim 2 of patent No. 1,789,496 required only a single tube and, since only a two-electrode piezo-electric crystal was needed, stabilized both low and high frequencies. Plaintiff himself states that the oscillator circuit of claim 2 of patent No. 1,789,496 is the "preferred" element in a combined transmitting and receiving system. Plaintiff here seems to be attempting to disclaim his distinctive improvements over the prior art which made his application patentable. The use of any kind of electro-mechanical vibrator under claim 3 of patent No. 1,789,496 or of a prior art Cady piezo-electric oscillating circuit under claim 1 in a combined transmitting and receiving system was not the "dominating new result" contributed by the plaintiff to the art of frequency stabilization of such combinations. Saranac Automatic Mach. Co. v. Wirebounds Patents Co., 1931, 282 U. S. 704, 51 S. Ct. 232, 75 L. Ed. 634. The plaintiff in so construing the claims of his patent No. 1,789,496 ignores their patentable features. However, as stated in Palmer Pneumatic Tire Co. v. Lozier, 6 Cir., 1898, 90 F. 732, 744: "* * * One cannot extract an essential element of his invention from a former patent, without which the former patent would not have been granted, and make it the subject of a subsequent patent. * * *" See also Miller v. Eagle Manufacturing Co., supra, and Otis Elevator Co. v. Portland Co., supra.

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(3) Plaintiff further argues that the Patent Office Examiner in ordering a division of plaintiff's original application, ruled that the invention of patent No. 2,133,642 and that of patent No. 1,789,496 to be two separate and distinct inventions, and that such a ruling by the Patent Office Examiner as stated in In re Cady, 1935, 77 F. 2d 106, 109, 22 C. C. P. A., Patents, 1190, 1195 "should not be lightly overruled." But it is not necessary for the disposition of the present action for us to decide whether or not the two patents may possibly cover separate inventions. We only hold that the generic patent No. 2,133,642 when read specifically on the accused combined transmitting and receiving systems discloses no invention distinct and separate from that of patent No. 1,789,496.

With respect to combined transmitting and receiving systems utilizing the Pierce oscillator, such as the accused structures, the plaintiff has suffered no hardship because of the delayed issuance of his basic patent No. 2,133,642. The plaintiff by means of patent No. 1,789,496 has already received the full seventeen years protection granted him by law on such systems. We cannot now extend that monopoly under the mantle of patent No. 2,133,642. Saranac Automatic Mach. Co. v. Wirebounds Patents Co., supra.

The cases relied upon by the plaintiff are distinguishable in that, unlike the case at bar, they involved either the earlier issued divisional patent being an improvement on the later issued patent, Thomson-Houston Electric Co. v. Ohio Brass Co., 6 Cir., 1897, 80 F. 712, or the patents covering separate and distinct inventions, In re Carlton, 1935, 77 F. 2d 363, 22 C. C. P. A., Patents, 1223; General Electric Co. v. P. R. Mallory & Co., 2 Cir., 1924, 298 F. 579 or the non-expiration of the patents in controversy, Badische Anilin & Soda Fabrik v. A. Klipstein & Co., C. C. S. D. N. Y. 1903, 125 F. 543.

The judgment of the District Court is vacated and the case is remanded to that court for entry of judgment for defendant. Defendant recovers costs on appeal.

APPENDIX F

Decision of U. S. Court of Appeals, First Circuit

(Decided March 30, 1955)

UNITED STATES COURT OF APPEALS,

FIRST CIRCUIT.

No. 4902.

George Washington PIERCE,

Plaintiff-Appellant,

v.

HEWLETT-PACKARD COMPANY *et al.*,

Defendants-Appellees.

Argued Jan. 6, 1955.

Decided March 30, 1955.

Rehearing Denied May 2, 1955.

Before MAGRUDER, Chief Judge, and WOODBURY and HARTIGAN, Circuit Judges.

HARTIGAN, Circuit Judge.

This is an appeal from an order of the United States District Court for the District of Massachusetts entered October 22, 1954, denying the plaintiff's motion for a preliminary injunction and granting the defendants' motion for partial summary judgment. In his complaint the plaintiff alleged infringement of six patents including claims 51, 52, 54, 55, 56 and 61 to 68 inclusive, of patent No. 2,133,642. The defendants, after the plaintiff moved for a preliminary injunction confined to the defendants' asserted infringement of the above enumerated claims of patent No. 2,133,-

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642, moved for a partial summary judgment declaring those claims invalid. The district court in granting the defendants' motion based its decision on the ground that this Court in American Communications Co. v. Pierce, 1 Cir., 1953, 208 F. 2d 763, certiorari denied, 1954, 347 U. S. 944, 74 S. Ct. 639, 98 L. Ed. 1092, rehearing denied 347 U. S. 970, 74 S. Ct. 775, 98 L. Ed. 1111; had adjudicated these enumerated claims void for double patenting.

The plaintiff bases his appeal in effect on two grounds: (1) that this Court in American Communications Co. v. Pierce, supra, did not hold these claims to be invalid for double patenting and (2) that these claims are not invalid for double patenting.

The plaintiff in his construction of our opinion in the American Communications Co. case has, as Judge Wyzanski so aptly phrased it, ignored the main thrust of that opinion.

In our decision we relied on the law set forth in Miller v. Eagle Manufacturing Co., 1894, 151 U. S. 186, 14 S. Ct. 310, 38 L. Ed. 121, and Palmer Pneumatic Tire Co. v. Lozier, 6 Cir., 1898, 90 F. 732. It is not necessary now to repeat the language we cited in the American Communications Co. case from the Miller and Palmer Pneumatic Tire Co. opinions. It is enough to say that we found in the American Communications Co. case that the plaintiff in patents Nos. 1,789,496 and 2,133,642 made only one distinctive contribution to the "Progress of Science and useful Arts," U. S. Const. Art. I, § 8, and that was the invention of a two electrode piezo-electric crystal in a single vacuum tube circuit. The utility of this invention was that it obtained to a much greater extent than had been previously possible a constant frequency of oscillations.

The plaintiff now contends that this Court did not understand that the result obtained under his earlier patent No. 1,789,496 was a constant *beat* frequency resulting from the difference in the frequency of oscillations of the receiver

and the frequency of oscillations of the transmitter. This beat is comparable to the beat produced when two tuning forks are caused to vibrate at slightly different frequencies, but in place of the tuning forks are two oscillating circuits, one in the transmitter and one in the receiver. But there is no element of invention in the idea that if one employs two circuits each of which produces oscillations at constant or stabilized frequencies the beat resulting from the difference between these two frequencies would be more stabilized and constant than would be the case if each of the circuits produced oscillations at frequencies which could not be fully controlled. In other words, it is obvious that if a transmitter is able to operate at a constant frequency and the corresponding receiver also operates at a constant frequency that any beat resulting from their combination will also be more constant than would be the case if the receiver or transmitter or both were unable to operate at a constant frequency.

The plaintiff cannot claim that patent No. 1,789,496 is a valid invention merely on the ground that through it a beat is produced for in Kintner v. Atlantic Communication Co., D. C. S. D. N. Y. 1917, 241 F. 956, the use of oscillating circuits to obtain a beat was shown to be the subject of a patent antedating the plaintiff's application by almost twenty years. The plaintiff also cannot successfully contend that his earlier patent No. 1,789,496 constitutes a valid invention merely because through the employment of prior art electromechanical vibrators it obtains a more constant beat, for prior to the plaintiff's application for his patent electromechanical vibrators had been used in an attempt to stabilize the frequency of oscillations of an electric circuit. Although these earlier electromechanical vibrators were less efficient than the plaintiff's two electrode piezoelectric crystal in maintaining a constant frequency of oscillations, they did achieve some control over the frequency of oscillations and consequently when employed in trans-

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mitting and receiving equipment a more constant beat would be produced than had been possible in apparatus employing such electromechanical vibrators.

1 (1, 2) The plaintiff received patent No. 1,789,496 only because of his contribution of a device which stabilized the frequency of oscillations of an electric circuit. Without this device the patent would not have been granted. The plaintiff cannot extract this essential element and make it the subject of a subsequent patent. Palmer Pneumatic Tire Co. v. Lozier, supra, 90 F. at page 744; see Application of Horneman, 1952, 194 F. 2d 108, 39 C. C. P. A., Patents, 866. The Pierce oscillator, the subject of patent No. 2,133,512, rather than the production of a constant beat, is the essential distinguishing feature of combination patent No. 1,789,496. See Application of Coleman, 1951, 189 F. 2d 370, 39 C. C. P. A., Patents, 1156.

In Palmer v. John E. Brown Mfg. Co., 1 Cir., 1899, 92 F. 925, cited by the plaintiff, the patentee's combination patent was sustained on the ground that the invention of a quilting machine which was the result of combining the patentee's "mechanical movement", the subject of his basic patent, with a workholder and sewing machine required perception as such combination was not an obvious one. In the instant case, the inclusion of the plaintiff's piezo electric oscillator in a transmitting and receiving system did not involve any element of perception, as the principal purpose of the oscillator, if not its only purpose, was in the transmission or reception of intelligence by means of high frequency currents.

(3) The plaintiff in 1924 applied for one patent but the Patent Office erroneously required a divisional application with regard to the claims now found in patent No. 1,789,496. The Patent Office thus in effect stated that the plaintiff had two separate inventions, but we are not bound by such a holding and the patent in issue will not be sustained merely

because of a requirement of division ordered by the Patent Office.

(4) The plaintiff contends that section 121 of the Patent Act of 1952[1] should be applied by the Court in the instant case and that this statute would prevent the use of the plaintiff's earlier patent as a reference in this case. However, the statute expressly refers to patents "* * * issuing on an application with respect to which a requirement for restriction under this section has been made * * *." The Patent Act of 1952 took effect on January 1, 1953. Plaintiff's patent No. 2,133,642 was granted on October 18, 1938. It was, therefore, impossible for the plaintiff's patent to have been issued on an application which was required to be restricted under the 1952 Act and consequently § 121 is inapplicable in the instant case. See Application of Eisler, 1953, 203 F. 2d 726, 40 C. C. P. A., Patents, 913.

The judgment of the district court is affirmed.

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1. 35 U. S. C.

"§121. *Divisional applications*

"If two or more independent and distinct inventions are claimed in one application, the Commissioner may require the application to be restricted to one of the inventions. If the other invention is made the subject of a divisional application which complies with the requirements of section 120 of this title it shall be entitled to the benefit of the filing date of the original application. A patent issuing on an application with respect to which a requirement for restriction under this section has been made, or on an application filed as a result of such a requirement, shall not be used as a reference either in the Patent Office or in the courts against a divisional application or against the original application or any patent issued on either of them, if the divisional application is filed before the issuance of the patent on the other application. If a divisional application is directed solely to subject matter described and claimed in the original application as filed, the Commissioner may dispense with signing an execution by the inventor. The validity of a patent shall not be questioned for failure of the Commissioner to require the application to be restricted to one invention."

APPENDIX G

Decision of U. S. Court of Appeals, First Circuit

(Decided June 30, 1960)

UNITED STATES COURT OF APPEALS

FIRST CIRCUIT.

No. 5529.

Helen Russell PIERCE, Executrix,
Plaintiff-Appellant,

v.

AMERICAN COMMUNICATIONS COMPANY, INC., *et al.*,
Defendants-Appellees.

Heard Nov. 2, 1959.

Decided June 30, 1960.

Before WOODBURY, Chief Judge, and HARTIGAN and ALDRICH, Circuit Judges.

WOODBURY, Chief Judge.

This is another chapter in protracted litigation in this and other circuits involving a group of patents for electrical systems and apparatus for use primarily in the art of radio communication issued to the late George Washington Pierce.[1] This time we have before us four appeals by the plaintiff below. One pair of appeals is from a single final judgment entered in two cases consolidated in the District Court for the purpose of hearing and trial which, with costs to the defendants, (1) granted their motions for summary

1. Dr. Pierce died during the pendency of the present actions which were prosecuted thereafter by the present appellant, his widow and executrix.

judgment and denied like motions in each case by the plaintiff with respect to four patents, Nos. 2,133,642, 2,133,645, 2,133,646 and 2,133,648, and (2) dismissed the plaintiff's complaints and granted the defendants' counterclaims for declarations of invalidity as to all claims of the above patents and also two others, Nos. 2,133,643 and 2,266,070. The other pair of appeals is from the denial of a motion by the plaintiff under Rule 59 (e) F. R. Civ. P., 28 U. S. C. A., to alter or amend the above judgment and from the denial of her motion to correct docket entries. All four appeals were consolidated and docketed as a single case in this Court.

This chapter in the litigation over the Pierce patents opened in 1951 with a complaint by the patentee against American Communications Company, Inc., American or American Communications hereinafter, charging it with infringing the six patents already mentioned and still another one, No. 2,133,644.[2] In that suit both parties moved under Rule 56 F. R. Civ. P. for partial summary judgment as to thirteen claims (claims 51, 52, 54, 55, 56 and 61 to 68 inclusive), of the basic patent of the group, No. 2,133,642. Holding the above claims valid and infringed, the District Court granted the plaintiff's motion and denied the defendant's. On appeal, however, this court reversed. American Communications Co., Inc. v. Pierce, 1 Cir., 1953, 208 F. 2d 763. In our view the thirteen claims involved were invalid, wherefore we remanded for entry of a judgment for the defendant.

In April, 1954, soon after our decision in the American case, the patentee filed a complaint in the court below charging Mackay Radio and Telegraph Company, Inc., Mackay hereinafter, with infringing the six patents enumerated above. The two cases proceeded on their separate ways in the District Court until September, 1958, when that court

2. Somewhere along the line this patent seems to have dropped out of the case.

granted the defendants' motions for a joint trial. Prior to that time, however, in January, 1958, the court below had granted motions by both defendants for summary judgment insofar as four of the six patents in suit were concerned but had denied the motions with respect to the other two which we shall refer to hereinafter as the '643 and '070 patents. After an extended trial without a jury the court below concluded that all claims of the two latter patents were invalid. Wherefore it entered the final judgment with respect to all six patents, and soon thereafter the orders denying the plaintiff's motions from which the plaintiff below has taken these appeals.

We first turn our attention to the four patents as to which the District Court granted the defendants' motions for summary judgment.

The District Court held that all of the claims of all of these patents were invalid for double patenting for the reason that in substance and essence they claimed the same invention disclosed and covered in the claims of a prior patent, No. 1,789,496, issued to Pierce on January 20, 1931, which, of course, expired seventeen years later on January 20, 1948. This earlier patent issued on an application filed on January 18, 1928, as a division by Patent Office order of an application filed on February 25, 1924, which in the Commissioner's belief described more than one invention. It covered in its three claims radio transmitting and receiving systems each with a two electrode electromechanical vibrator, preferably in the form of a piezo-electric crystal in a single vacuum tube circuit the utility of which was to obtain constant frequency of the oscillations of each system to a far greater extent than had previously been possible. To gain some idea of what we understand this to mean it will first be necessary to describe briefly and in general what is known in the art as the heterodyne receiving system which was not new with Pierce.

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Decision of U. S. Court of Appeals, First Circuit

A radio antenna picks up radio waves sent out by the sending or transmitting station. That is to say, it operates as a conductor in a magnetic field (radio waves are electromagnetic), and as it intersects or cuts through the field an electric current is induced in the antenna of the same frequency as that sent out by the transmitting station. The electric current induced in the antenna first passes through the radio frequency amplifier in the receiving set where its power is increased but its frequency is not changed. From the amplifier the current next goes to the first detector, known as the mixer or converter, where the heterodyning action takes place.

This action can best be described by illustration. Let us suppose that the electric current picked up by the antenna and entering the first detector from the frequency amplifier has cyclical variations of 50,000,000 per second, *i. e.*, 50 megacycles. For reasons we need not explain this frequency is far too high; in some way it must be reduced. This is the function of the local oscillator in the receiving set which furnishes a frequency slightly different from that of the sending station to produce a "beat." This "beat" produced by the difference between the frequency of the oscillations of the receiver and the frequency of the oscillations of the transmitter, as we pointed out in another chapter in the litigation over the Pierce patents,[3] is comparable to the beat produced when two tuning forks of slightly different frequency are caused to vibrate at the same time. Now let us assume that the local oscillator in the receiving set furnishes a frequency of 50,001,000 cycles, although it would make no difference if it furnished a frequency sightly lower than that of the sending station. The important thing is variation between frequencies of the sending and receiving stations. In our illustration this

3. Pierce v. Hewlett-Packard Co., 1 Cir., 1955, 220 F. 2d 531, 532, certiorari denied 1955, 350 U. S. 833, 76 S. Ct. 69, 100 L. Ed. 744.

variation is 1,000 cycles, a frequency better adapted for ultimate conversion to sound in the receiving set.

The radio process from this point on to the production of audible sounds is not too important for present purposes, and we need not attempt to describe it.

Dr. Pierce was not the inventor of this heterodyning action, nor was he the first person to use a piezo-electric crystal in an oscillator. Prior to Pierce a Dr. Cady had patented an oscillator in which the crystal controlled oscillations produced elsewhere in the circuit but did not itself produce oscillations. Pierce's contribution to the art was to show an oscillator wherein the crystal not only controlled the frequency, as in Cady, but itself actually produced the frequency or oscillations. In Cady the circuit could oscillate independently of the crystal since the crystal did not produce but merely controlled oscillations produced elsewhere in the circuit. The advantage of Pierce's system over Cady's is that a change of constants in the circuit, which might result from a battery running down, will not affect the oscillations produced by the oscillator since the crystal itself produces the oscillations.

The practical value of Dr. Pierce's invention was to permit the use of very high frequencies in radio communication. This he accomplished by keeping the oscillations of both the sending and the receiving stations at practically constant frequency by means of his vibrators or oscillators in the preferred form of piezo-electric crystals in a single vacuum tube circuit. Obviously close control of the oscillations at one station without similar close control at the other would not be of much value in radio communication. In the specification of his expired 1,789,496 patent he says that his "* * * invention is particularly useful where constant-frequency sources are used at the transmitting station and also at the receiving station." He illustrates the value of his invention in the specification of his expired patent as follows:

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"Both in telegraphy and in telephony, the oscillations of the system will be kept at practically constant frequency by the vibrators, making it possible, for example, to use a very high frequency, with all the advantages flowing therefrom. For example, consider a frequency of 50,000,000 cycles, corresponding to 6-meter wave length. A control of the frequency to within one tenth of one percent would obviously involve a difference in variation of 50,000 cycles. With a variation in frequency as great as 50,000 cycles, the signal is continually running off the setting of the receiving system, with the result that the operator has to shift continuously, trying to catch it here and catch it there. A part of the signal is detected, but a large part is often lost. According to the present invention, on the other hand, it is possible to maintain the frequency to within 1/100,000 of one percent. This involves a variation of only five cycles on a frequency of 50,000,000. Indeed, by proper care, it is possible to keep the variation within only one cycle.

"The imporfance of this beat reception will be realized when it is reflected that the local oscillator used for voice modulation may have a frequency of 1,000 cycles. A variation of 50,000 cycles or for that matter, a variation of only 500 cycles, is a serious problem for beat reception under such circumstances. A variation of only five cycles, on the other hand, or, for that matter, as much as 50 cycles, could readily be handled."

We turn now to consideration of the four Pierce patents as to which the court below granted the defendants' motions for summary judgment.

Appendix G

Decision of U. S. Court of Appeals, First Circuit

(1) In the American Communications case and again in the Hewlett-Packard case, both cited hereinabove, this court held that thirteen claims of patent No. 2,133,642 made no new contribution to the progress of science and the useful arts. In our view those thirteen claims did not cover an invention essentially distinct and separate from the invention covered in claim 2 of Pierce's expired patent No. 1,789,496. It is true that this expired patent covered specifically transmitting and receiving systems having the Pierce piezo-electric crystal vibrator "in combination." Nevertheless in the Hewlett-Packard case at pages 532 and 5[illegible] of 220 F. 2d we said: "The plaintiff received patent No. 1,789,496 only because of his contribution of a device which stabilized the frequency of oscillations of an electric circuit. Without this device the patent would not have been granted. The plaintiff cannot extract this essential element and make it the subject of a subsequent patent." That is to say, we considered the nub and heart of Pierce's expired patent to be his oscillator, meaning by that, his piezo-electric crystal in a single vacuum tube circuit, and that no separate inventive concept was involved in using two of his oscillators in combination, one a transmitting and the other in a receiving system. Moreover, in both of the above cases we held that on the issue of double patenting it was of no consequence that the later issued patent was the basic one and that the earlier patent issued on a divisional application perhaps erroneously required by the Patent Office. At page 769 of 208 F. 2d we said:

> "With respect to combined transmitting and receiving systems utilizing the Pierce oscillator, * * * the plaintiff has suffered no hardship because of the delayed issuance of his basic patent No. 2,133,642. The plaintiff by means of patent No. 1,789,496 has already received the full seventeen years protection

granted him by law on such systems. We cannot now extend that monopoly under the mantle of patent No. 2,133,642."

The District Court clearly and, of course quite correctly, recognized that in the American Communications case it was bound by our previous opinion in that case to hold the thirteen claims of the 2,133,642 patent which we had then passed upon invalid.[4] That court, of course, also recognized quite correctly that it was not similarly bound in the Mackay Radio and Telegraph case, Pierce v. Mackay Radio and Telegraph Co., D. C., 169 F. Supp. 351. But, concluding that there was nothing in the affidavits etc. before it in these cases substantially different from the material before this court on the two previous instances when we passed on the validity of these thirteen claims, it held in the light of the law as laid down in our decision that those claims were also invalid as against Mackay. Then, finding that the thirteen claims of the 2,133,642 patent already held invalid were typical of all the claims of the patent—that none of the remaining claims of the patent covered anything substantially different from the thirteen invalid claims—it granted the defendants' motions for summary judgment as to that patent *in toto*. It said:

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4. In our opinion in the Hewlett-Packard case at page 532 of 220 F. 2d we said: "It is enough to say that we found in the American Communications Co. case that the plaintiff in patents Nos. 1,789,496 and 2,133,642 made only one distinctive contribution to the 'Progress of Science and Useful Arts,' U. S. Const. Art. I, §8, and that was the invention of a two electrode piezo-electric crystal in a single vacuum tube circuit." The hope may be vain but perhaps now counsel for the plaintiff will give over the attempt to convince this court that all we held in the American Communications case was that the thirteen claims of the 2,133,642 patent then before us were merely unenforceable so that it is still open to the patentee to prove the validity of those claims vis-a-vis not only Mackay but also American.

Appendix G

Decision of U. S. Court of Appeals, First Circuit

> "It is clear that all of the claims of patent No. 2,133,642 are for the same invention. They vary in defining the Pierce piezo-electric oscillator in broad terms or in closely limited language, or in similarly describing other elements of the system closely or broadly, or in claiming the use of the Pierce oscillator generally in an electrical system or in a specific circuit of that system. But what is described in all of them is substantially the same—the use of a piezo-electric crystal in a single vacuum tube system for the purpose of stabilizing the oscillations of the system. Hence what was said by the Court of Appeals as to certain of these claims applies equally to all of them."

We agree with the District Court.

No useful purpose would be served by our undertaking to analyse separately each of the remaining ninety odd claims of the 2,133,642 patent. It will have to suffice for us to say that studying these claims in the light of the specification it seems to our lay minds that all they describe in substance and effect in their varying language is the use of the basic Pierce oscillator disclosed in patent No. 1,789,496 in a variety of circuits for essentially the same purpose.

A little more must be said, however, with respect to the last two claims of the No. 2,133,642 patent, claims 105 and 106. Claim 105 does not describe the Pierce oscillator but claim 106 obviously does. Essentially, however, both claims undertake to cover changing the temperature of a piezo-electric crystal to vary its oscillations. In essence they read substantially the same to cover "A method of controlling the frequency of vibration ["operation" in claim 106] of a piezo-electric crystal that comprises changing the temperature of the crystal from normal room temperature to a temperature to cause oscillation at a desired substantially precise frequency of vibration."

Appendix G

Decision of U. S. Court of Appeals, First Circuit

There is little if any disclosure in the patent to support these claims. All that is said in the specification with respect to temperature is that in the preferred form of the invention described therein "* * * the disturbing effects,—such as those produced by changes of temperature, * * *—on the frequency of oscillations usually amount to less than one one-hundredth of one percent of the frequency." But whether the claims have any adequate disclosure in the specification to support them or not, it is evident that there is no description in them or anywhere in the patent of any device or means for varying the temperature of the crystal from room temperature. If valid, they would cover any and all means for changing the temperature of the crystal from room temperature to make the frequency of its vibrations to some undisclosed extent independent of room temperature. If these claims are anything more than an attempt to monopolize an already observed phenomenon of piezo-electric crystals, at the most they cover only a result obtained by varying the temperature of the crystal from room temperature. They are vague at the precise point of any possible novelty.

The next patent in this group, No. 2,133,645, in its 24 claims covers the Pierce piezo-electric crystal oscillator either standing alone or in the receiving set of the transmitter-receiver combination claimed in expired patent No. 1,789,496. The claims vary in their language. Some are broad covering the oscillator generally; some are narrow covering the oscillator in specific combinations with old elements of receiving sets. All of them, however, claim no more than the same oscillator claimed in Pierce's expired patent No. 1,789,496 and again in his patent No. 2,133,642. Obviously the claims are invalid for double patenting.

Much the same may be said of the two remaining patents in this group. Patent No. 2,133,646 covers the Pierce

oscillator coupled to a harmonic selector or frequency multiplier circuit. In order to produce frequencies of over 3,000,000 cycles Dr. Pierce found it necessary to use a harmonic frequency of his piezo-electric crystal for the reason that to construct a crystal capable of producing a frequency of over 3,000,000 cycles it was necessary to cut or grind the crystal so thin (to less than a millimeter) that it was too weak for handling and use. Since a usefully strong crystal of itself produced only oscillations of relatively low frequency, it is essential to couple the oscillator with a harmonic selector circuit in order to produce oscillations of high frequency which are harmonics or multiples of the frequency produced by the crystal itself.

It is clear from reading the patent that frequency multiplication by harmonic selector circuits was not new in the radio art at the time this patent was issued. Nor was there any novelty in coupling an oscillator with a harmonic selector. All that was new in this patent was the introduction of a source of constant frequency oscillations in the form of Pierce's oscillator coupled with a harmonic selector circuit. It is clear that the only novelty disclosed in the claims of this patent is the Pierce oscillator. Indeed, the circuit covered in this patent is identical with a circuit described and shown in Fig. 2 of Pierce's expired patent. We therefore conclude that the patent is void for double patenting over the 1,789,496 patent.

Some of the claims of the remaining patent in this group, No. 2,133,648, cover crystals of specified dimensions and shapes to produce specific frequencies of oscillations, and other claims cover an impedance in the form of a variable capacitance, inductance or resistor inserted in the circuit containing the oscillator to control the frequency of its oscillations. The first group of claims covering shapes and dimensions of the piezo-electric crystal were

held by the court below to be invalid for double patenting over the No. 1,789,496 patent which had already claimed the use of crystals in general. That expired patent does not specifically disclose that a piezo-electric crystal may be cut to particular shapes or sizes to produce specific frequencies of oscillation. Nevertheless, it might well be inferred from the claim of crystals generally that specific shapes and sizes of crystals were covered, for if it was not already common knowledge that shape and size govern the frequency of crystals, as early as 1922 Professor Cady had pointed out in an article entitled "The Piezo-electric Resonator" that the frequency of the oscillations of a quartz crystal, said to be a preferred type of crystal in Dr. Pierce's expired patent, is a function of the dimensions of the crystal.

The second group of claims covering the insertion of an impedance in the oscillator circuit was held by the court below to be invalid for lack of novelty and for double patenting. This is clearly correct, for Professor Cady in his reissue patent Re 17,245 of 1929 showed an impedance, in the form of a variable condenser connected across a coil, in an oscillator circuit containing a piezo-electric crystal to control the frequency of the oscillations of the circuit. The only novelty in this group of claims, and their essential patentable element, is the use of Dr. Pierce's particular circuit wherein the piezo-electric crystal itself produced the oscillations instead of merely controlling oscillations produced elsewhere in the system as in Cady. But, of course, this, as we have repeatedly pointed out, is the same invention disclosed and covered in Pierce's expired patent.

As to these last three patents the plaintiff-appellant contends that summary judgment was improper and that she should have been allowed to present evidence on the issue of their validity at a trial. We are at a loss to per-

ceive what evidence in addition to that before the court below would shed any further light on the issue. Nor do counsel for the plaintiff-appellant in their brief tell us what additional evidence they would like to present. They merely assert in their brief that they have additional evidence, and in their reply brief complain that they would have expatiated further on the question of the validity of these three patents had this court not limited their brief to 160 pages. The simple answer to this is that if they had directed their argument to essential basic issues instead of posing and repetitiously arguing twenty-eight more or less irrelevant separate questions, they would have had ample opportunity to present their argument to this court on these three patents within the space allowed them.

In our view the District Court correctly analysed the foregoing patents and applied correct principles of law to the evident facts. In accord as to patents Nos. 2,133,642, 2,133,646 and 2,133,648 see Judge Layton's opinion in Pierce v. Allen B. Du Mont Laboratories, Inc., D. C. Del. 1959, 178 F. Supp. 84.

We come now to the two patents as to which there was a trial in the court below, the '643 and the '070 patents as we have referred to them hereinabove.

(2) The 120 claims of the '643 patent cover various features to be incorporated in holding devices for crystals, each intended to cope with some particular problem arising from their use in radio oscillating circuits. For convenience the District Court divided the claims of this patent which were submitted to it for consideration in the plaintiff's post-trial brief into five groups.[5] We find that group-

5. The plaintiff contends that there is also a sixth group of claims in this patent which, by her own admission correspond with a group of claims in the '070 patent. What we shall have to say with respect to the '070 patent will dispose of this asserted sixth group of claims.

ing entirely appropriate. Indeed, the District Court's grouping is appropriate for all of the claims of this patent and all of its claims, if not put in issue by the plaintiff in her pleadings, were put in issue by the defendants' counterclaims for declaratory judgments of invalidity. We shall follow the District Court's technique of decision.

That court found that the first group of claims, Nos. 10 and 74, cover a holder for the piezo-electric crystal which is hermetically sealed by filling any openings in it with wax, celluloid varnish or some similar substance to keep out dust or moisture which would interfere with the satisfactory operation of the crystal. The plaintiff contends that these claims also cover securing the crystal in its holder to prevent bodily movement therein and establishing electrical connection with the crystal so secured in such a way as to permit its free vibration with substantially no restriction.

Insofar as the claims cover these latter elements they do so in language only of function. Claim 74 in only slightly different language recites the same combination covered in claim 10, and claim 10 reads as follows:

> "A piezo-electric-crystal holder comprising in combination a hermetically sealed closure and means within said closure for securing a piezo-electric crystal therein and establishing electrical connection therewith, while permitting the free vibration of said piezo-electric-crystal with substantially no restriction."

Only a hermetically sealed enclosure can possibly be said to be covered in anything but functional language.[6]

6. At any rate, we shall cover Dr. Pierce's technique for holding crystals in our discussion of a subsequent group of claims of this patent.

Therefore that is the only element covered by this group of claims which we need to consider.

If Dr. Pierce was indeed the first to discover that the operation of piezo-electric crystals would be affected by dust, moisture etc., as to which there is considerable doubt, we think it obvious that the first expedient to occur to any reasonably intelligent person working in the field to solve the problem would be to seal the crystal hermetically, to prevent the intrusion of these foreign elements. Moreover, as the District Court pointed out, hermetically sealing a piezo-electric crystal to protect it from contact with water was shown in a British patent to one Langevin in 1921, No. 145,691, for a submarine signalling device using a piezo-electric crystal. And, U. S. Patent No. 1,495,429 issued to Nicholson in 1924 covers sealing such crystals in wax. These claims are clearly invalid.

The second group of claims covers mechanical means for mounting a piezo-electric-crystal apparatus in an circuit, insofar as specified at all, by means of a socket and plug device comparable, if not similar, to the familiar telephone socket or "jack," for the purpose of facilitating the ready exchange of crystals of different frequency in an electrical circuit. The evidence is undisputed that the use of plugs and jacks to provide means for rapidly changing the components of an electrical system was old by the time Pierce made his alleged invention. Plugs and jacks such as those shown by Pierce had long been used in the telephone art. Indeed, a patent to Ponitz, No. 763,164 shows the use of plugs and jacks for switching coils in a wave meter and a patent to Varley, No. 772,591, shows plug and jack mountings for ready removal of induction coils in electric circuits. This group of claims is also clearly invalid over the prior art.

The third group of claims covers a holder for a piezo-electric crystal with a screw-threaded mounting therein for

one electrode so that it can readily be moved closer to or further away from the crystal; the purpose being to vary the amount of electric current flowing to the crystal in order to vary its frequency. We have already pointed out that Professor Cady in his reissue patent Re 17,245 showed the use of an impedance in the form of a variable condenser connected across a coil to vary the flow of current to a piezo-electric crystal to vary its frequency. Moreover, Professor Cady in the same article referred to hereinabove pointed out that if the air space between a crystal and one of its electrodes is increased the frequency of the crystal will be slightly raised. And it is clear from the evidence and the District Court found that a variable condenser is the full equivalent of Dr. Pierce's adjustable electrode. In fact, the court found, and we think it evident, that Dr. Pierce's adjustable electrode is nothing more than a form of variable condenser. Certainly there is nothing novel in a screw-threaded adjustment. Perhaps Dr. Pierce's device permitted fine adjustment of the frequency of his crystal but it certainly cannot be called an invention.

The fourth group of claims cover resilient means for holding a crystal in place in its holder, for if it were free to move about within its holder the changes in air space would produce small variations in its frequency, and if it were tightly clamped in its holder severe dampening of its vibrations would occur. The resilient means shown is a brass spring. This spring forms one of the electrodes, the crystal rests upon the other, and is so designed that it can be screw-adjusted to exert only slight pressure on the upper face of the crystal. The District Court held these claims invalid over the disclosures in a paper delivered by Dr. Pierce in October 1923 at a meeting of the American Academy of Arts and Sciences, and published in its proceedings, wherein he described in words and by reference to a drawing a "Mounting for Quartz Crystal of Piezo-

electric Oscillator" as a hard rubber frame a little thicker than the quartz with sheets of brass to serve as electrodes screwed to the two faces of the frame and, "A thin sheet of spring brass (marked 'filler') *, * * inserted between some of the electrodes and the quartz, in such a way that only a light pressure [is] exerted on the quartz."

The plaintiff contends vigorously that the reference to the thin sheet of spring brass marked "filler" in the drawing does not refer to a spring but only to a "filler" designed to hold the crystal in place by its weight. We do not know why "spring brass" should be referred to unless to imply resilient pressure. But however that may be, the paper certainly discloses the problem of holding the crystal in place in its mounting by light pressure upon it, and, given the problem, a light spring would seem to us to be the first expedient to occur to anyone interested in solving it. We see no invention in these claims.

The fifth and final group of claims cover clamping crystals at their points of quiescence known as their nodal points to permit the crystals to be held rigidly yet with minimal dampening effect on their vibrations.[7] Dr. Pierce was not, and does not claim to have been, the first to discover that vibrating bodies, including piezo-electric crystals, have areas or points of quiescence, or nodal points, at which the vibrating body can be held without dampening its vibrations. Prior to Pierce, Professor Cady clearly disclosed that pressure could be applied to a crystal at its nodal points without dampening its vibrations in his article to which we have already referred. Furthermore, in the

7. The District Court aptly illustrated what is meant by the nodal point, or point or area of quiescence of a vibrating body, by reference to the common tuning fork. This device as is well known consists of two prongs joined like the tines of a two-tined fork to form a U-shaped structure with a handle at the bottom of the U where the instrument can be held without interfering with its vibrations as would be the case if it were held by either of the vibrating prongs.

fourth group of claims considered above Dr. Pierce disclosed the utility to prevent minor changes of frequency of clamping the crystal in its holder, and to do so in such a way as to interfere as little as possible with its free vibration he suggested a light spring electrode. Given this knowledge, and knowledge that a crystal could be held at its nodal point, the novelty in this fifth group of claims must reside in the means they disclose for holding the crystal at its nodal points.[8] Two means for holding crystals at their nodal points in a predetermined position in their frames are disclosed in this group of claims. One means consists of electrodes having narrow projections so positioned as to touch opposite faces of a flat crystal at its mid point where the nodal line for the longitudinal vibration of the crystal is located. The other means consists of oppositely disposed flat electrodes positioned to clamp a lenticular shaped crystal between them by gripping the crystal at its mid point of greatest bulge which lies on the nodal line of such crystals. In short, Dr. Pierce shaped either the electrodes or the crystal in such a way as to accomplish his end. And the shapes he employed certainly were not difficult to conceive. We quite agree with the District Court that an obvious expedient to accomplish Dr. Pierce's purpose is merely to give the crystal or its electrodes such a shape that the electrodes will touch the crystal only at its nodal points, leaving the rest of the crystal free to vibrate without restriction. Certainly there is no inventive novelty in the shapes employed to achieve the purpose. This group of claims is invalid for lack of invention.

So much for the '643 patent. Now we come to the last one in litigation here, the '070 patent.

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8. There is no suggestion that Dr. Pierce contributed anything toward discovering the location of the nodal points or areas of quiescence of a crystal.

(3) The 30 claims of this patent can conveniently be divided into two groups, one group covering an evacuated sealed container for the crystal and the other covering immersion of this holder in a constant temperature bath. The District Court held both groups of claims invalid over the prior art and also invalid for functionality.

The evacuated holder for the crystal represents a definite advance over the hermetically sealed crystal holder claimed in the 2,133,643 patent considered above. The hermetically sealed holder prevented moisture, dust, etc. from affecting the frequency of the crystal, to be sure, but it did not eliminate two other phenomena harmful to its operation known as air column resonance and corona discharge. Obviously evacuation of the holder did as much to keep out dust, moisture etc. as hermetically sealing it. But evacuating the air from the holder did more in that it also prevented to a large extent air column resonance and corona discharge. But, as the court below pointed out, evacuated containers for components of electrical systems have been known for at least as long as Edison's electric light bulb. Moreover, the evidence is clear that long before Pierce, Langmuir, at least, had pumped more air out of De Forest's vacuum radio tube to reduce the harmful effects of gases therein two of which are air column resonance and corona discharge. No more needs to be said to show that these claims are invalid over the prior art.

The single claim covering immersion of the crystal holder in a constant temperature bath, if not also invalid over the prior art, is certainly invalid for functionality. It reads:

> "Apparatus of the character described comprising an evacuated receptable, means for maintaining the receptacle at constant temperature, and an electro-mechanical vibrator contained in the receptacle."

Appendix G

Decision of U. S. Court of Appeals, First Circuit

In the specification, to which the reader is invited to refer for a description of the apparatus, all that is said about temperature control is that the sealed vessel, referring obviously to the evacuated crystal holder, "whether of metal or glass, may be kept in a constant temperature bath, as illustrated in Fig. 2." And all that Fig. 2 shows is a rectangle drawn around a vibrator receptacle, the area between the rectangle and the receptacle labelled "Constant Temperature Bath." No structure is covered in the claim or described anywhere in the patent nor is there any disclosure or suggestion whatever as to how constant temperature might be maintained in the bath. The claim is clearly and obviously void for functionality.

(4) We have still to consider the other pair of appeals by the plaintiff below, her appeal from the orders of the District Court denying her motions to amend the judgment and to correct docket entries. The appellant's contention, insofar as her motion to amend the judgment is concerned, rests basically on two propositions. One is that she was deprived of a fair and full opportunity to present her case at the hearing on the defendants' motions for summary judgment, and the other is that not all of the claims of all of the patents were put in issue so that the judgment should be amended to cover only those specific claims of the patents which were in issue. She says in substance that at an informal conference with the court below prior to the date set for hearing on the motions for summary judgment her counsel "understood" that the hearing on the motions "would be restricted to the issue relating only to the said 'reasoning' of this Court, with respect" to the thirteen claims of the 2,133,642 patent considered in the American Communications and Hewlett-Packard cases. She says: "There was no understanding that there was to be considered any issue of double patenting with respect

to the remaining claims of this basic patent 2,133,642, or that there was to be considered any issue of double patenting with respect to any of the claims of any of the other patents in suit." Wherefore she contends that her counsel was taken completely by surprise when he came to the hearing on the motions for summary judgment and quite unprepared to present his case on the broader issues then taken up for decision. Counsel for the appellee gives quite a different version of the informal conference preceding the hearing on the motions. He says that the only limitation placed on the scope of the hearing by the court at the informal conference was that no consideration would be given to the issue of the functionality of the claims.

The informal conference was not reported so we have no positive way of knowing which version is correct. The action of the court in denying the motions, however, satisfies us that it agreed with the defendants' version. At least, the plaintiff has not established that her version is correct.[9]

The appellant bases her contention that not all of the claims of all of the patents here involved were put in issue largely on the answers she gave to certain interrogatories propounded by the defendants. We do not find the answers to which she refers in the record appendix to her brief. It will suffice to say that it is clear that all of the claims of all of the patents involved were put in issue by the pleadings and that the plaintiff appears to be the only one who did not so understand.

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9. Plaintiff also complains that the defendants filed an affidavit considerably less than ten days prior to the hearing on the motion for summary judgment, and another one after the hearing. However, plaintiff was allowed to reply to the first of these affidavits, and there is nothing to show that she would not have been permitted to reply to the second, had she wished to do so.

Appendix G

Decision of U. S. Court of Appeals, First Circuit

(5) There is no substance whatever in the appellant's contention that a docket entry on September 15, 1958, to the effect that the defendants' motion to consolidate the two cases was allowed without objection should be deleted. She says that on that date there was no such motion pending and consequently there was nothing to which she could have objected.

It appears that at a pre-trial conference defendants' counsel, they were the same in both cases, suggested that the cases be consolidated to which plaintiff's counsel did not then disagree, that in January, 1958, the court entered its summary judgment as to the first four patents considered herein, that in July, 1958, the defendants formally moved for a joint trial of the cases as to the two patents remaining for disposition and that on September 15, 1958, the court allowed the motion. There was obviously no need for joint trial of the cases as to the first four patents after summary judgment had been entered as to them. And there certainly was no error in consolidating the cases as to the two patents remaining for trial. We fail to see the slightest need to amend the docket entry to show specifically that the cases were consolidated only for the purpose of a trial as to the two patents not disposed of on the motions for summary judgment. Moreover, we fail to see how an amendment of the docket entry is of any consequence whatever to the appellant.

Judgment will be entered affirming the judgment and orders of the District Court.

APPENDIX H

Decision of U. S. Court of Appeals, Third Circuit

UNITED STATES COURT OF APPEALS

THIRD CIRCUIT

No. 13279

HELEN RUSSELL PIERCE, Executrix of the Last Will and Testament of GEORGE WASHINGTON PIERCE, Deceased,
Appellant,

v.

ALLEN B. DU MONT LABORATORIES, INC.

Argued Oct. 7, 1960 and May 22, 1961

Decided Nov. 29, 1961

Rehearing Denied Dec. 26, 1961

Before BIGGS, Chief Judge, and
HASTIE and FORMAN, Circuit Judges

HASTIE, Circuit Judge

This appeal has been taken from a judgment of a district court in a patent infringement suit. The trial court held that claims 3, 26, 40, 51, 52, 54-56, and 61-68 of Pierce Patent No. 2,133,642 were invalid for double patenting over the earlier Pierce Patent No. 1,789,496.[1] D. Del. 1959, 178 F. Supp. 84. For convenience the numbers of the two patents will be designated throughout this opinion as "'642" and "'496".

1. While the pleadings and the trial covered alleged infringement of several related patents, appellant has elected to base this appeal solely upon controverted questions as to the validity and the infringement of '642, which is the basic patent.

Appendix H

Decision of U. S. Court of Appeals, Third Circuit

Patent '496 was issued in 1931 on an application filed in 1928. It expired some six years before the 1954 filing of the present suit. Patent '642 was issued in 1938 after a considerable history which will be detailed later. That patent expired after the filing, but before the trial, of this case.

I

A preliminary question must be decided because the inventor George Washington Pierce, who filed this complaint, died before trial. Over the objection of the defendant, the court ordered that Pierce's widow and executrix, Helen Russell Pierce, be substituted as plaintiff. D. Del. 1957, 154 F. Supp. 368. Although the defendant prevailed on the merits below, it urges as appellee in this court that we need not and should not reach the merits of the appeal, but rather should rule that the cause of action was extinguished by the death of the original plaintiff. This jurisdictional problem is our first concern.

Appellee's argument, that a cause of action for damages for infringement of a patent, which has expired since that infringement, does not survive the death of the owner of the patent, proceeds in two steps. First, it is pointed out that property in patents exists solely by virtue of federal statutory law and that the incidents of that property are defined and determined by the patent statutes. This is the principle of Crown Die & Tool Co. v. Nye Tool & Machine Works, 1923, 261 U. S. 24, 43 S. Ct. 254, 67 L. Ed. 516. Second, it is argued that, since causes of action for patent infringement thus depend upon federal statutes for existence and definition, they must lapse with the death of the patent owner, unless a federal statute affirmatively provides for their survival. This is a non sequitur. Certainly, no such conclusion is required by the Crown Die case, which did not involve the problem of the effect of the death of a patentee

upon the statutory right to collect damages for past infringement. Moreover, it is a necessary, if not articulate, premise of appellee's argument that some rule or principle of law outside of the patent statutes cuts off the cause of action when the patent owner dies. This must be the case simply because the patent law itself gives no guidance on this question. Whether the conclusion shall be that the right survives or that it does not, the controlling rule must be derived from a source other than the patent statutes.

In practice federal courts, required to decide whether various federal statutory causes of action survive, have been explicit and consistent in holding that, where the right-creating statute says nothing about survival, resort to common law conceptions as evolved in English and American decisions is appropriate. Van Beeck v. Sabine Towing Co., 1959, 360 U. S. 342, 57 S. Ct. 452, 81 L. Ed. 685; Schreiber v. Sharpless, 1884, 110 U. S. 76, 3 S. Ct. 423, 28 L. Ed. 65; Sullivan v. Associated Billposters & Distributors, 2d Cir., 1925, 6 F. 2d 1000, 42 A. L. R. 503; Walsh v. New York, N. H. & H. R. R., C. C. D. Mass. 1909, 173 F. 494, aff'd, 1912, 223 U. S. 1, 32 S. Ct. 169, 56 L. Ed. 327. Such inquiry discloses a common law rule of survival, originally applied to a limited group of damage claims for tortious invasion of property rights, but subsequently broadened toward sanctioning the survival of claims for redress of injuries to monetary interests generally. Van Beeck v. Sabine Towing Co., supra; Kirk v. Commissioner of Internal Revenue, 1st Cir., 1950, 179 F. 2d 619, 15 A. L. R. 2d 1031.

This approach has resulted in rulings that various federal statutory causes survive without statutory stipulation. The question of survival arises frequently in civil suits for injury to business caused by violations of the antitrust laws. These claims are held to survive. Barnes Coal Corp. v. Retail Coal Merchants Ass'n, 4th Cir., 1942, 128 F. 2d 645; Moore v. Backus, 7th Cir., 78 F. 2d 571, 101 A. L. R. 379,

cert. denied, 1935, 296 U. S. 640, 56 S. Ct. 173, 80 L. Ed. 455; Sullivan v. Associated Billposters & Distributors, supra. In a different area, the Supreme Court has held, and this court has recognized, that a dependent's right under the Merchant Marine Act, 46 U. S. C. A. §688 and the Federal Employers' Liability Act, 45 U. S. C. A. §51 et seq. to recover the pecuniary loss he has suffered through the death of the decedent, survives the death of the dependent and may be exercised by his administrator. Van Beeck v. Sabine Towing Co., supra; Wade v. Rogala, 3d Cir., 1959, 270 F. 2d 280, 284.[2]

(1, 2) Of course, the principle "that a patent is property, protected against appropriation * * * by individuals * * * has long been settled." See Hartford-Empire Co. v. United States, 1945, 323 U. S. 386, 415, 65 S. Ct. 373, 387, 89 L. Ed. 322. For purposes of survival we can see no reason for putting actions for damage suffered through patent infringement on a different basis from the above cited invasions of other property rights.

As a separate point appellee argues that the often stated rule that penal claims do not survive is applicable here because the patent statute under which this suit is brought authorizes the recovery of treble damages. However, this argument has not prevailed in the above mentioned situation of treble damage suits under the antitrust laws. Barnes Coal Co. v. Retail Coal Merchants Ass'n, supra.

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2. More recently, one court of appeals has extended the Van Beeck result to allow a survivor's administrator to recover for an employee's pain and suffering under Section 9 of the Federal Employers' Liability Act. Dellaripa v. New York, N. H. & H. R. R., 2d Cir., 1958, 257 F. 2d 733, 72 Harv. L. Rev. 558 (1959). In so doing, however, the court completely rejected the traditional distinction between "personal" and "property" rights as concerns survival. 257 F. 2d at 735. We are not asked to go this far in the present case. See also Baumet v. United States, 2d Cir., 1949, 177 F. 2d 806, cert. denied, 1950, 339 U. S. 923, 70 S. Ct. 611, 94 L. Ed. 1346.

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Moreover, the statute involved in the present case lends itself to the separation of the basic compensatory award of actual damages from any permissible additional award of punitive character. The statute provides primarily for the award of "damages adequate to compensate for the infringement", 35 U. S. C. 284, 1958. Thereafter, it authorizes "the court * * * [to] increase the damages up to three times the amount found or assessed". Therefore, even assuming that the severable provision for the discretionary multiplication of damages is penal, this affords no justification for cutting off the basic right to compensatory recovery. In the posture of this case no more than that need be decided.

Appellee makes a final argument that the claim for damages for past infringement does not survive because the law does not permit a patentee to assign such a claim apart from the patent itself. However, any considerations of policy which oppose the separation of a cause of action for past infringement from the right of present enjoyment of a patent cease to be relevant after the expiration of the patent has eliminated the right of present enjoyment. It is not surprising, therefore, that such authority as there is on the point supports the assignability of a past infringement claim after the patent has expired. Ross v. City of Fort Wayne, 7th Cir., 1894, 63 F. 466; Tompkins v. St. Regis Paper Co., D. C. N. D. N. Y. 1915, 226 F. 734 aff'd 2d Cir., 1916, 236 F. 221; May v. Saginaw County, C. C. E. D. Mich. 1887, 32 F. 629. Thus, it does not help appellee to borrow the rules of assignability as guides to the determination of survival.

Finally, on this entire question of survival no policy consideration has been suggested which would make it unfair to allow a claim for past infringement to be exercised by an administrator in the interest of the estate of a deceased patentee. It is just as undesirable to permit a

patent infringer to retain the fruits of his wrongdoing in this situation as it is when the patentee himself is suing. Compare Dellaripa v. New York, N. H. & H. R. R., 2d Cir., 1958, 257 F. 2d 733. Thus broad policy and technical analysis both indicate that appellee's contentions are not sound.

We are the more confident of the correctness of our view of this matter because the same result has been reached in carefully reasoned opinions by two of the three district courts which have fully analyzed the problem. Armstrong v. Allen B. Du Mont Labs., Inc., D. Del. 1955, 137 F. Supp. 659; Armstrong v. Emerson Radio & Phonograph Corp., S. D. N. Y. 1955, 132 F. Supp. 176. Contra Van Choate v. General Electric Co., D. C. D. Mass. 1917, 245 F. 120.

II

We come now to the merits of the controversy. Was the trial court correct in ruling patent '642 invalid for double patenting over the patentee's earlier '496? Both patents embody Pierce's invention of a new method and apparatus utilized in electrical circuits to produce and sustain oscillations at more constant frequency than had theretofore been achievable, particularly in high frequency systems. Because inability to control frequency variations had hampered the development of high frequency radio communication, the effective incorporation of Pierce's invention in both transmitting and receiving circuits was a major achievement in an important field. Pierce's essential teaching was that the introduction of a two electrode piezoelectric crystal of his devising into a vacuum tube circuit as a mechanical vibrator accomplished the desired stabilization. This novel and unquestionably inventive device and procedure for frequency control in oscillating electrical systems will hereafter be called the Pierce oscillator. The patent infringement alleged in this case is the use of this

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device by appellee in two types of television transmitting system, in a mobile transmitter-receiver and in a time-controlled

As early as 1924 Pierce filed a patent application containing many claims, both broad and narrow, covering the Pierce oscillator in various combinations and asserting many beneficial effects. In 1928, after the elimination of certain claims which are not relevant here, the still pending original application contained all of the claims which were later to be divided and granted separately in patent '1 and patent '642. Pierce then eliminated the [illegible] claims from this pending original application and incorporated them in a divisional application which matured into patent '496 issued in January, 1931. For present purposes it is sufficient that his first issued patent claimed a [illegible] transmitting and receiving system wherein the new stabilizing Pierce oscillator was joined in effective combination with other elements of such a system which, admittedly, were old and familiar in the art.

More than a year before patent '496 issued the patent office had allowed what remained of the original application, including a generic claim to the Pierce oscillator as a means of frequency stabilization in any oscillator system. Indeed, it is clear and not disputed that as early as September 1929 Pierce could have obtained a comprehensive patent, claiming and protecting his oscillator generically, merely by paying a final fee on his approved original application. However, he elected not to pay this fee within the prescribed time. Instead, he allowed this opportunity to pass and later made a timely renewal of his application as the patent law authorizes. Counsel representing the Pierce interests now tells us that Pierce thus voluntarily delayed the issuance of a patent on his generic claim because of his desire to have an interference declared with a rival inventor, one Miller, whose claims conflicted with those of Pierce and were a cloud on his title to the new

oscillator. In any event, Pier[illegible] renewed his basic application in 1930. An interfer[illegible]ce was declared in 1932 and the dispute with Miller was finally adjudicated in 1938 when this court ruled that Miller had derived his alleged invention from Pierce. Miller v. National Broadcasting Co., 3 Cir., 1935, 79 F. 2d 657. Thereafter, in October 1938 a patent on the remaining claims of the original Pierce application, including the generic claim to the Pierce oscillator, was issued as patent '642. The infringement alleged in the present action occurred less than seventeen years after the issuance of this patent but after the expiration of the earlier patent '496.

(3) Both parties to the present litigation recognize that under our patent system, based as it is upon statutory monopoly limited to a seventeen year period, it is an inherent principle that an inventor is not entitled to the issuance of two patents at different times for the same invention. However, in administering the rule against double patenting it is not always clear what constitutes a single invention.

(4) Perhaps the most frequently cited statement of the rule appears in Miller v. Eagle Mfg. Co., 1894, 151 U. S. 186, 198, 14 S. Ct. 310, 315, 38 L. Ed. 121, where the Supreme Court said:

> "* * * no patent can issue for an invention actually covered by a former patent, especially to the same patentee, although the terms of the claims may differ; that the second patent, although containing a broader claim, more generical in its character, than the specific claims contained in the prior patent, is also void; but that where the second patent covers matter described in the prior patent, essentially distinct and separable from the invention covered there-

by, and claims made thereunder, its validity may be sustained.

"In the last class of cases it must distinctly appear that the invention covered by the later patent was a separate invention, distinctly different and independent from that covered by the first patent: in other words, it must be something substantially different from that comprehended in the first patent. It must consist in something more than a mere distinction of the breadth or scope of the claims of each patent. If the case comes within the first or second of the above classes, the second patent is absolutely void."

Since Miller v. Eagle, courts have repeatedly ruled that an inventor's separate applications embodying the same inventive concept afford proper bases for the issuance of separate patents at different times only if one of them also embodies an additional inventive concept not present in the other. In other words, the difference between the claims of the two applications must itself be inventive. Weatherhead Co. v. Drillmaster Supply Co., 7th Cir., 1955, 227 F. 2d 98; In re Woodsome, 1926, 56 App. D. C. 138, 10 F. 2d 1003; Palmer Pneumatic Tire Co. v. Lozier, 6th Cir., 1898, 90 F. 732; In re Copeman, 1943, 135 F. 2d 349, 30 C C P A 962; In re Laughlin, 1931, 48 F. 2d 921, 18 C C P A 1239; Ex parte Gump, Pat. Off. Bd. App., 1948, 83 U. S. P. Q. 351. But cf. Traitel Marble Co. v. U. T. Hungerford Brass & Copper Co., 2d Cir., 1927, 22 F. 2d 259.

A typical application of this rule appears in American Bell Tel. Co. v. National Tel. Mfg. Co., C. C. D. Mass. 1901, 109 F. 976, aff'd on other grounds, 1st Cir., 1905, 119 F. 893. The inventor's original patent application contained a generic claim for a novel telephone transmitter. But before final action on this generic claim, a patent was granted on a co-pending divisional application for a telephonic com-

munication system incorporating this transmitter as its only novel element. In holding that a second patent could not lawfully be granted on the transmitter itself, the court analyzed the situation in a way that is helpful here.

> "[The first patent] confers a monopoly of the transmitter with a restriction or limitation. The patent in suit confers a monopoly without restriction. The patents are nevertheless both for the 'same invention,' both in a legal and a practical sense. [The earlier patent] * * * presents the familiar case of an inventor taking a patent with an unnecessary limitation. The commissioner has exhausted his power, and cannot afterwards give him a general grant for all uses. The argument that the use of the transmitter or of the receiver alone would not infringe * * * [the earlier patent] is immaterial. It does not prove that the claim is for a * * * [different] invention, but merely that the claim does not cover all the uses which might have been covered, had the patentee not chosen to take a claim for a restricted use. That the two patents are not coextensive does not affect the application of the rule against double patenting." 109 F. at 1033.

(5) Similarly, in the present case the Pierce oscillator is the only new and inventive feature of the combination patent '496. Moreover, the Pierce oscillator performs no different function and achieves no significantly different result in this combination than when used in any other circuit. Thus, invention inheres not in any unusual characteristic or result of the particular combination, but merely in the normal functioning of a novel component. Yet, patent '642 was issued thereafter for this very component in its general adaptation to its normal role. The controlling doctrine, elaborated in the excerpt we have

quoted from the American Communications case is stated more tersely in Palmer Pneumatic Tire Co. v. Lozier, supra: "One cannot extract an essential element of his invention from a former patent, without which the former patent would not have been granted, and make it the subject of a subsequent patent." 90 F. at 744. This line of reasoning has already led the Court of Appeals for the First Circuit to find the patent in suit invalid. Pierce v. Hewlett-Packard Co., 220 F. 2d 531, cert. denied, 1955, 350 U. S. 833, 76 S. Ct. 69, 100 L. Ed. 744. But cf. Pierce v. Aeronautical Communications Equipment, Inc., 5th Cir., 1958, 255 F. 2d 458.

But even if the foregoing analysis is persuasive in most cases where successive patents have reflected but one inventive concept, it is argued that the second patent should be granted where circumstances beyond the applicant's control have resulted in patent office approval of a divisional application before administrative action has been completed on an earlier or simultaneously filed basic application. The point is made that such administrative delay, for which the applicant has no responsibility and over which he has no control, should not deprive him of the second partially overlapping generic claim needed to give him full protection for his invention pursuant to his initial application, even though the more restricted monopoly first granted to him is thereby extended somewhat beyond its original term. This argument is said to be reinforced in this case by the additional fact that Pierce eliminated the claims for a radio transmitting and receiving system from his original application and incorporated them in a divisional application only after a patent examiner had made it clear that he was unwilling to approve a patent on the original application unless there should be such division.

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Where such protection for a longer time than the patent law contemplates has in fact resulted solely from administrative delay in the patent office, it may well be that a balancing of the equities will justify the allowance of both patents. Fehr v. Activated Sludge, Inc., 7th Cir., 1936, 84 F. 2d 948; see Union Typewriter Co. v. L. C. Smith & Bros., C. C. W. D. Pa. 1909, 173 F. 288, 297, aff'd, 3d Cir., 1910, 181 F. 966. Of course the patentee's equitable position is strengthened where it appears as an additional fact that the patent office itself has required a division that resulted in harmful delay.[3] In most such cases the harm of double patenting will be slight because administrative delay in allowing the earlier application is not likely to be long enough to extend the original monopoly much beyond its proper seventeen year term.

But this is not the present case. Here, the inventor, by merely paying his final fee could have obtained his generic patent more than a year before he actually obtained the narrower patent '496. He made a considered election to postpone his acquisition of the broader monopoly until he was sure that its exploitation would not be hampered by conflicting claims of a rival inventor. Yet, somewhat later, when the divisional application, which certainly was no less

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3. The court below found that "at no time did the Examiner actually order a division". Rather, "seeing that he would either have to divide or suffer a final rejection by the Examiner and appeal therefrom [the appellant], voluntarily divided". Whether a formal administrative order requiring a division must be appealed and judicially affirmed before the second of the resultant two patents is protected against a claim of double patenting and consequent invalidity, is a matter of dispute in the cases. With National Tube Co. v. Steel & Tubes, Inc., 3d Cir., 1937, 90 F. 2d 52, and In re Cady, 1935, 77 F. 2d 106, 22 CCPA 1190, contrast Remington Rand Business Service, Inc. v. Acme Card System Co., 4th Cir., 71 F. 2d 628, cert. denied, 1934, 293, U. S. 622, 55 S. Ct. 236, 79 L. Ed. 710, and In re Woodsome, supra. See also In re McKee, 1935, 79 F. 2d 905, 23 CCPA 717.

embarrassed than the generic one by the Miller claims, won patent office approval he paid his final fee promptly and accepted the patent. This, therefore, is not a case where administrative action prevented the inventor from having his more comprehensive application patented first, but rather where the choice has been the inventor's, dictated by his own judgment of possible economic advantage. We think these circumstances are not such as to justify an exception to the general rule and policy against double patenting. Cf. Miller v. Eagle Mfg. Co., supra.

(6) One additional observation seems pertinent. It was the view of the court below that the combination patent '496 gave the patentee some measure of protection for the Pierece oscillator as such, since the oscillator was the only inventive feature of the claimed combination. Were this point essential to our decision it would be necessary to decide whether this view can be squared with recent decisions of the Supreme Court limiting the protection which a patent claiming only a particular combination can give to a constituent element of that combination. Aro Mfg. Co. v. Convertible Top Replacement Co., 1961, 365 U. S. 336, 81 S. Ct. 599, 5 L. Ed. 2d 592; Mercoid Corp. v. Minneapolis-Honeywell Regulator Co., 1944, 320 U. S. 680, 64 S. Ct. 278, 88 L. Ed. 396; Mercoid Corp. v. Mid-Continent Investment Co., 1944, 320 U. S. 661, 64 S. Ct. 268, 88 L. Ed. 376. We decide merely that patent '496 protected Pierce in the use of the Pierce oscillator in radio transmitting and receiving systems. We have already pointed out that it is the extension of this monopoly beyond its proper seventeen year term which invalidates the generic patent.

One possibility of avoiding this unwarranted extension of monopoly has been suggested; namely, that the later generic patent may be held valid except that it shall not

be deemed to protect such adaptations of the invention to radio transmitting and receiving as have already been covered by the earlier combination patent. A rational patent system might include such a refinement. Indeed, such a reconciliation of partially overlapping successive patents is made where an inventive difference is found to exist between their claims. E.g., Washburn & Moen Mfg. Co. v. Norwood (The Barbed Wire Patent), 1892, 143 U. S. 275, 12 S. Ct. 450, 36 L. Ed. 161. But, where there is no inventive difference between the claims of the two patents the partial validation of the more comprehensive claims of the second overlapping patent seems unwarranted. Ex parte Gump, supra. Rather, the patentee who has justification for supplementing his patented claims without embodying any new invention is left to the established reissue procedure for enlarging his monopoly without extending its term. See Union Typewriter Co. v. L. C. Smith Bros. Typewriter Co., 3d Cir., 1910, 181 F. 966, 969.

(7) Finally, appellee complains that the court below denied its motion for attorneys' fees under 35 U. S. C. §285. In denying this motion the court quite properly found "that no bad faith on the part of the plaintiff has been shown". This has been a hard and fairly fought case involving difficult and doubtful points of law. It certainly discloses no such imposition or unfairness as the statute contemplates in its limited authorization of counsel fees. Cf. Hardinge Co., Inc. v. Jones & Laughlin Steel Corp., 3d Cir., 1960, 275 F. 2d 37.

The judgment will be affirmed.

APPENDIX I

U. S. Patent No. 1,789,496, January 20, 1931

(See Pages 91 to 96 Opposite ☞)

Jan. 20, 1931. G. W. PIERCE 1,789,496

ELECTRICAL SYSTEM

Original Filed Feb. 25, 1924

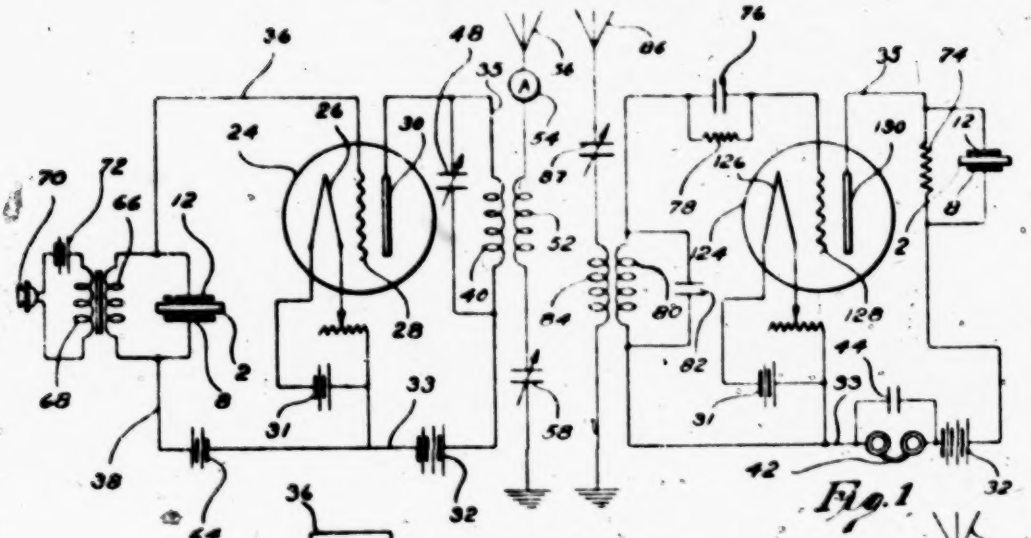

Fig. 1

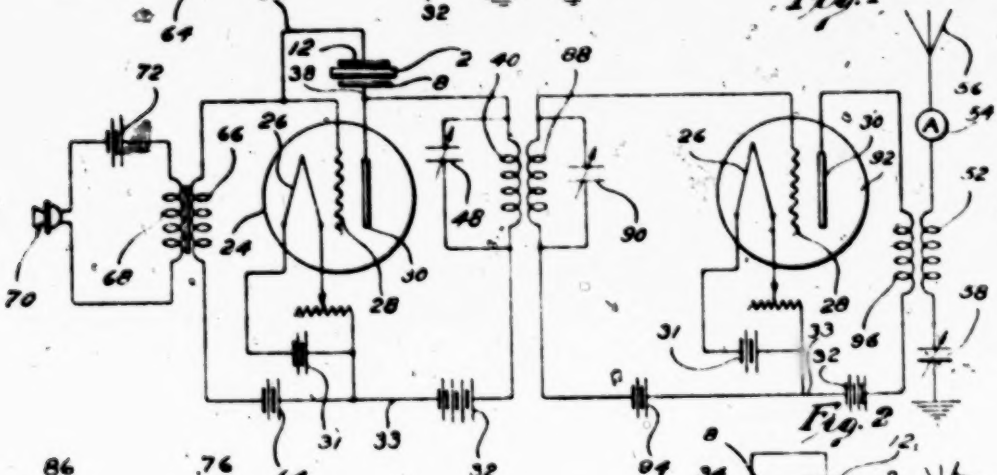

Fig. 2

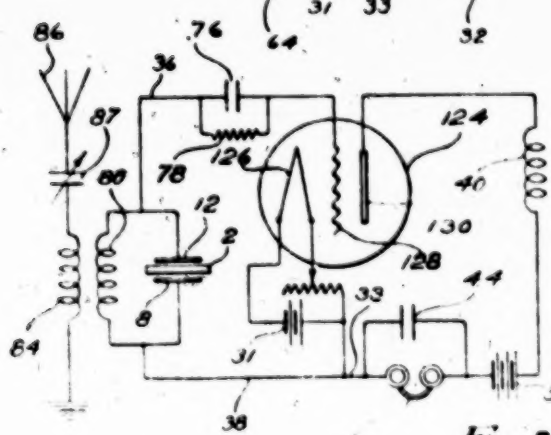

Fig. 3

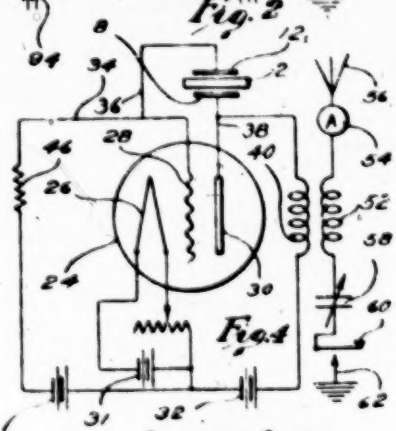

Fig. 4

Inventor
George W. Pierce
By David Rines
Attorney

Patented Jan. 20, 1931 92 1,789,496

UNITED STATES PATENT OFFICE

GEORGE W. PIERCE, OF CAMBRIDGE, MASSACHUSETTS

ELECTRICAL SYSTEM

Original application filed February 25, 1924, Serial No. 695,094. Divided and this application filed January 18, 1928. Serial No. 247,469.

The present invention relates to the transmission and reception of intelligence.

In radio telegraphy, it is customary to transmit signals by means of electric waves with a frequency that is desired to be constant. In the reception of such signals, a receiving system is often employed comprising an electric circuit traversed by an oscillatory current of frequency such as to give audible beats with the received signal frequency. For this purpose, particularly when high-frequency waves are employed, it is important to keep constant the frequency of the receiving circuit. In the reception of radio-telephone signals, too, it is useful to maintain a constant-frequency oscillation at the receiving station to beat superaudibly with the incoming signals for superheterodyne reception. In radio telephony and radio telegraphy, and in carrier-current systems where transmitting or receiving is effected by means of a carrier wave, also, the carrier frequency may be suppressed at the sending station, the side bands only being gram of a radio-telegraphic transmitting system and apparatus.

A complete transmitting-and-receiving system is diagrammatically shown in Fig. 1. In order to simplify the drawings, and to render the description more easily understood, the complete transmitting-and-receiving system is omitted from the other figures, which, therefore, show separate transmitting systems and receiving systems. The system of Fig. 1 is more particularly designed for radio-telephone work, but corresponding connections for transmitting or receiving by radio telegraph or by telegraph or telephone over line wires will be obvious to those skilled in the art.

The constant frequency of the transmitting and receiving circuits, according to a preferred embodiment of the present invention, is attained by the interaction upon the system of electromechanical vibrators, like piezoelectric crystals. Such vibrators have the property of executing mechanical vibrations under vibratory electrical stimulus and

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The present invention has for its chief objects to provide an improved method of and systems and apparatus for transmitting and receiving electrical signals and to reduce interference to a minimum; also, to provide for an accurate control of the receiving-station frequency, and for a cooperation of frequency control at the transmitting station with control at the receiving station.

Other and further objects of the invention will be explained hereinafter and will be pointed out in the appended claims, it being understood that it is intended to cover in the appended claims all the novelty that the invention may possess.

In the accompanying drawings, Fig. 1 is a diagram of circuits and apparatus illustrating the present invention in its preferred form; Fig. 2 is a similar diagram of a modified radio-telephonic transmitting system and apparatus, using power amplification; Fig. 3 is a similar diagram of a modified receiving system; and Fig. 4 is a similar diagram of a radio-telegraphic transmitting system and apparatus.

A complete transmitting and receiving system is diagrammatically shown in Fig. In order to simplify the drawings, and to render the description more easily understood, the complete transmitting-and-receiving system is omitted from the other figures, which, therefore, show separate transmitting systems and receiving systems. The system of Fig. 1 is more particularly designed for radio-telephone work, but corresponding connections for transmitting or receiving by radio telegraph or by telegraph or telephone over line wires will be obvious to those skilled in the art.

The constant frequency of the transmitting and receiving circuits, according to a preferred embodiment of the present invention, is attained by the interaction upon the system of electromechanical vibrators, like piezo-electric crystals. Such vibrators have the property of executing mechanical vibrations under vibratory electrical stimulus and, conversely, of developing electrical potentials as a result of their mechanical vibrations, as is now well known, and as is explained in a copending application, Serial No. 695,094, filed February 25, 1924, of which the present application is a division. For convenience, the action of the electric forces to cause mechanical deformation will be termed "stimulation" and the development of electromotive force by the displacement will be termed "response."

The electromechanical vibrator, shown as a piezo-electric body 2, is differently disposed in the different diagrams, so as to illustrate a few of the many different ways in which the vibrator may be employed. It is to be understood, however, that the vibrator disposition, in a particular diagram, is not specific to that diagram, but that the vibrator may be similarly disposed in the other diagrams. The oppositely disposed surfaces of the vibrator 2 are provided with opposed electrodes 8 and 12. One of the electric axes of the crystal 2 is assumed, for concreteness, to be in the direction of the thickness of the crystal plate.

A vacuum tube 24 is diagrammatically

shown in the transmitting system provided with three sensitive elements or electrodes, namely, a filament 26, a grid 28 and an anode or plate 30. The filament 26 is connected with a filament-heating battery 31. A plate battery 32 is connected with the filament 26 by a conductor 33, and with the plate 30 by a conductor 35. A load 40, shown in the form of an inductance coil having a distributed capacity resistance, is connected between the battery 32 and the plate 30. A tuning condenser 48 may be connected in parallel with the load, or the power of the system may, for some purposes, be increased by electrically tuning some other element.

In the transmitting system shown in the left-hand portion of the diagram of Fig. 1, and in Figs. 2, 3 and 4, the electrode 12 of the electromechanical vibrator is shown connected by a conductor 36 with the grid. The other electrode 8 is connected in Figs. 1 and 3 by a conductor 38 with the filament 26, and in Figs. 2 and 4, to some point in the circuit of the plate 30. The vibrator is thus connected, in the transmitting-system portion of the diagram of Fig. 1 and in Fig. 3, between the filament and the grid of the vacuum tube; and in Figs. 2 and 4, between the grid and the plate. Other connections, too, may be used. Thus, in the right-hand or receiving-system portion of the diagram of Fig. 1, the vibrator is shown connected between the filament and the plate, in the plate circuit of the vacuum tube.

An impedance element 66 (Figs. 1 and 2), 80 (Fig. 3), or 46 (Fig. 4) may be connected in the grid circuit. In Figs. 1 and 3, the impedance element 66 is disposed in parallel with the vibrator. If desired, a biasing battery 64 may be employed to bias the grid 28 to a predetermined potential, so that the potential of the grid may fluctuate about the biased value.

The system will oscillate with a frequency determined by the frequency of some normal mode of mechanical vibration of the vibrator and independent of the electrical parameters of the circuits.

With this setting, the invention of the present application will now be explained, though it will be understood that the invention is not, in its broader aspects, limited to any particular arrangement of circuits and vibrator connections.

In order to adapt the invention for transmission, the coil 40 is coupled to a coil 52 in The same remark applies to reception along line wires as alternative to reception by an antenna. The coils 40 and 52 are so adjusted as to tune the system for the maximum current, as observable in the ammeter 54. The impedance element 66 may take the form of the secondary winding of a modulation transformer, as in Figs. 1 and 2. The primary winding 68 of the transformer may be connected to a microphone 70, in circuit with a source of energy, shown as a battery 72. The variations produced by the microphone will modulate the carrier oscillations of the system. The operation will be understood by persons skilled in the art without further description. The winding 66 of the modulation transformer may be replaced by a resistor of high resistance, with a new disposition of the microphone. Corresponding connections for transmitting by telegraph, or (as will presently appear) for receiving, will be obvious to those skilled in the art, as illustrated in Fig. 4. The frequency of a transmitting station so designed is very nearly constant and stable.

In the receiving system, too, as shown in Fig. 3, the vibrator 2 may be connected in the input circuit, between the filament 126 and the grid 128 of the receiving tube 124, the same as in the transmitting system of Fig. 1. In order to illustrate some of the many different ways in which the vibrator may be connected into circuit, however, it is illustrated in the receiving system at the right of Fig. 1 as connected in the output circuit, between the filament 126 and the plate 130, shunted by a bypass 74 for direct current. The bypass 74 may be a radio choke, an inductance winding, a resistor, or a combination of these. The bypass 74 is preferably so chosen that the circuits shall have parameters such as to make the system stably non-oscillatory when the crystal is removed or restrained from vibrating. A blocking condenser 76, shunted by a leak resistor 78, and a winding 80, shunted by a condenser 82, are shown in Fig. 1 connected in the grid circuit, between the filament and the grid. The winding 80 is coupled to a winding 84 in series with a receiving antenna 86 and a condenser 87, and is grounded or connected with a counterpoise. The antenna 86 will receive the radio signals transmitted from the antenna 56. A telephone receiver 42, with or without a bypass condenser 44, may be disposed in the plate circuit of the receiving

conductor 35. A load 40, shown in the form of an inductance coil having a distributed capacity resistance, is connected between the battery 32 and the plate 30. A tuning condenser 48 may be connected in parallel with the load, or the power of the system may, for some purposes, be increased by electrically tuning some other element.

In the transmitting system shown in the left-hand portion of the diagram of Fig. 1, and in Figs. 2, 3 and 4, the electrode 12 of the electromechanical vibrator is shown connected by a conductor 36 with the grid. The other electrode 8 is connected in Figs. 1 and 3 by a conductor 38 with the filament 26, and in Figs. 2 and 4, to some point in the circuit of the plate 30. The vibrator is thus connected, in the transmitting-system portion of the diagram of Fig. 1 and in Fig. 3, between the filament and the grid of the vacuum tube; and in Figs. 2 and 4, between the grid and the plate. Other connections, too, may be used. Thus, in the right-hand or receiving-system portion of the diagram of Fig. 1, the vibrator is shown connected between the filament and the plate, in the plate circuit of the vacuum tube.

An impedance element 66 (Figs. 1 and 2), 80 (Fig. 3), or 46 (Fig. 4) may be connected in the grid circuit. In Figs. 1 and 3, the impedance element 66 is disposed in parallel with the vibrator. If desired, a biasing battery 64 may be employed to bias the grid 28 to a predetermined potential, so that the potential of the grid may fluctuate about the biased value.

The system will oscillate with a frequency determined by the frequency of some normal mode of mechanical vibration of the vibrator and independent of the electrical parameters of the circuits.

With this setting, the invention of the present application will now be explained, though it will be understood that the invention is not, in its broader aspects, limited to any particular arrangement of circuits and vibrator connections.

In order to adapt the invention for transmission, the coil 40 is coupled to a coil 52 in the usual manner, as illustrated in Fig. 1. The coil 52 is connected, through a hot-wire ammeter 54, to an antenna 56, and through a tuning condenser 58, to the ground. These connections serve admirably for radio-telephone transmission. If the transmission is to be applied to a telephone line, the antenna and ground connection may be replaced by the well known connections to line wires.

transformer, as in Figs. 1 and 2. The primary winding 68 of the transformer may be connected to a microphone 70, in circuit with a source of energy, shown as a battery 72. The variations produced by the microphone will modulate the carrier oscillations of the system. The operation will be understood by persons skilled in the art without further description. The winding 66 of the modulation transformer may be replaced by a resistor of high resistance, with a new disposition of the microphone. Corresponding connections for transmitting by telegraph, or (as will presently appear) for receiving, will be obvious to those skilled in the art, as illustrated in Fig. 4. The freqeuncy of a transmitting station so designed is very nearly constant and stable.

In the receiving system, too, as shown in Fig. 3, the vibrator 2 may be connected in the input circuit, between the filament 126 and the grid 128 of the receiving tube 124, the same as in the transmitting system of Fig. 1. In order to illustrate some of the many different ways in which the vibrator may be connected into circuit, however, it is illustrated in the receiving system at the right of Fig. 1 as connected in the output circuit, between the filament 126 and the plate 130, shunted by a bypass 74 for direct current. The bypass 74 may be a radio choke, an inductance winding, a resistor, or a combination of these. The bypass 74 is preferably so chosen that the circuits shall have parameters such as to make the system stably non-oscillatory when the crystal is removed or restrained from vibrating. A blocking condenser 76, shunted by a leak resistor 78, and a winding 80, shunted by a condenser 82, are shown in Fig. 1 connected in the grid circuit, between the filament and the grid. The winding 80 is coupled to a winding 84 in series with a receiving antenna 86 and a condenser 87, and is grounded or connected with a counterpoise. The antenna 86 will receive the radio signals transmitted from the antenna 56. A telephone receiver 42, with or without a bypass condenser 44, may be disposed in the plate circuit of the receiving tube 124. Where the telephone is not needed, it may be replaced by an inductance, the primary winding of a transformer, or the input terminals of an amplifier, or it may be wholly short-circuited. The locally generated oscillations of the circuits of the tube 124 will beat with the oscillations received by the antenna 86, according to well-known principles, rendering the received

signal audible in the telephone 42, or giving them any required superaudible frequency for superheterodyne reception. These locally generated oscillations may also be employed to supply a suppressed carrier frequency if desired.

A system of this character is adapted to receive high-frequency radiations, to which the electrical tuning elements are adjusted, and to superimpose upon them the frequency of mechanical vibration of the vibrator. The two frequencies are thus coexistent at the same time, permitting beats to be produced.

A tunable transmitting system and a tunable receiving system such, for example, as are illustrated together in Fig. 1, each supplied with a suitable vibrator, may, the one transmit, and the other receive, constant oscillations of very high frequency. This has been done by me over considerable distances. Variations in frequency arise from many sources, for all the circuit constants or parameters are continuously varying. For example, the mere running down of the battery, thus changing its voltage, the variation of inductance, the aging of a condenser, deterioration of the vacuum tubes, or a mere change in temperature—these and many other factors each introduces changes in the circuit constants and produces a different frequency from the frequency intended. No such difficulties are encountered in accordance with the present invention. The frequency is maintained constant irrespective of the parameter variations. The constancy of the beat note and the consequent certainty of being always in adjustment to receive the given signals is found to be of great value, rendering possible the use of very high frequencies.

The beats render audible unmodulated telegraph signals. Superaudible beats may also be produced, in the case of telephone and telegraph reception, and these may be used for amplifying purposes, as in superheterodyne apparatus. The superposed frequencies may also be used to supply a carrier wave in a radio telephone system where the system operates by suppressed carriers. These results may be effected both in space-communication systems and in wire-communication systems. The invention is particularly useful where constant-frequency sources are used at the transmitting station and also at amplifying systems, as by a plurality of vacuum tubes; and one such system, adapted for transmission, is illustrated in Fig. 2. The connections are very much as in the transmitting system of Fig. 1, except that the winding 40, instead of being directly coupled to the winding 52 of the antenna circuit, is coupled to a winding 88 that is shunted by a condenser 90. The elements 88 and 90 may be tuned so as to pick off one of the many harmonics from the plate circuit of the master oscillating tube 24. The winding 88 is connected in the grid circuit of an oscillating vacuum tube 92, and that is biased by a battery 94. A winding 96 is connected in the plate circuit of the vacuum tube 92, and is coupled to the winding 52. The vibrator 2 determines the frequency of oscillation of the master oscillating circuit comprising the vacuum tube 24. The master oscillator, which may be of, say 5 watts, controls, through power amplification of the fundamental or a harmonic, the tube 92 that is adapted to yield an output of much higher power, say 50 watts, and so forth. The frequency of the master oscillator 24 may be caused to beat with the fundamental or the harmonics of the circuits of the tube 92; and the beat may be reduced to zero by suitably tuning the circuits of the tube 92; so that a large number of frequencies may thus be obtained. Such a system has been successfully operated by me, in practice, over a considerable distance. I have utilized harmonics of the device at frequencies of 20,000 kilo cycles per second, corresponding to an electric wave of fifteen meters wave length. This range may undoubtedly be extended in both directions. Any desired number of such amplifying units may be interposed in cascade, without in any way departing from the present invention.

A telegraphic transmitting apparatus according to the present invention is illustrated in Fig. 4. The coil 40 is coupled to the coil 52 in the usual manner, as before described. The coil 52 is connected, as before, through a hot-wire ammeter 54, to an antenna 56, and through a variable condenser 58, to a sending key 60. The key 60 is adapted to make and break contact with a grounded contact member 62. The method of telegraphing will be obvious to persons skilled in the art, and need not be further described.

the electrical tuning elements are adjusted, and to superimpose upon them the frequency of mechanical vibration of the vibrator. The two frequencies are thus coexistent at the same time, permitting beats to be produced.

A tunable transmitting system and a tunable receiving system such, for example, as are illustrated together in Fig. 1, each supplied with a suitable vibrator, may, the one transmit, and the other receive, constant oscillations of very high frequency. This has been done by me over considerable distances. Variations in frequency arise from many sources, for all the circuit constants or parameters are continuously varying. For example, the mere running down of the battery, thus changing its voltage, the variation of inductance, the aging of a condenser, deterioration of the vacuum tubes, or a mere change in temperature—these and many other factors each introduces changes in the circuit constants and produces a different frequency from the frequency intended. No such difficulties are encountered in accordance with the present invention. The frequency is maintained constant irrespective of the parameter variations. The constancy of the beat note and the consequent certainty of being always in adjustment to receive the given signals is found to be of great value, rendering possible the use of very high frequencies.

The beats render audible unmodulated telegraph signals. Superaudible beats may also be produced, in the case of telephone and telegraph reception, and these may be used for amplifying purposes, as in superheterodyne apparatus. The superposed frequencies may also be used to supply a carrier wave in a radio telephone system where the system operates by suppressed carriers. These results may be effected both in space-communication systems and in wire-communication systems. The invention is particularly useful where constant-frequency sources are used at the transmitting station and also at the receiving station.

The function performed by the piezo-electric crystal may be performed also by other vibrators similarly operating by internal stresses, such as the tuned magnetostriction vibrator of application Serial No. 158,452, filed January 3, 1927, and all such vibrators will be included in the claims under the generic term "electromechanical vibrator" or its equivalent.

The invention is readily adapted to power-condenser 90. The elements 88 and 90 may be tuned so as to pick off one of the many harmonics from the plate circuit of the master oscillating tube 24. The winding 88 is connected in the grid circuit of an oscillating vacuum tube 92, and that is biased by a battery 94. A winding 96 is connected in the plate circuit of the vacuum tube 92, and is coupled to the winding 52. The vibrator 2 determines the frequency of oscillation of the master oscillating circuit comprising the vacuum tube 24. The master oscillator, which may be of, say 5 watts, controls, through power amplification of the fundamental or a harmonic, the tube 92 that is adapted to yield an output of much higher power, say 50 watts, and so forth. The frequency of the master oscillator 24 may be caused to beat with the fundamental or the harmonics of the circuits of the tube 92; and the beat may be reduced to zero by suitably tuning the circuits of the tube 92; so that a large number of frequencies may thus be obtained. Such a system has been successfully operated by me, in practice, over a considerable distance. I have utilized harmonics of the device at frequencies of 20,000 kilocycles per second, corresponding to an electric wave of fifteen meters wave length. This range may undoubtedly be extended in both directions. Any desired number of such amplifying units may be interposed in cascade, without in any way departing from the present invention.

A telegraphic transmitting apparatus according to the present invention is illustrated in Fig. 4. The coil 40 is coupled to the coil 52 in the usual manner, as before described. The coil 52 is connected, as before, through a hot-wire ammeter 54, to an antenna 56, and through a variable condenser 58, to a sending key 60. The key 60 is adapted to make and break contact with a grounded contact member 62. The method of telegraphing will be obvious to persons skilled in the art, and need not be further described. The grid is connected with the filament by a conductor 34 having the impedance element 46, which may be used to give the grid a suitable potential about which its fluctuations occur about a zero value. If desired, however, the biasing battery 64 may be employed, as before described, in which event the fluctuations will taken place about the biased value.

Both in telegraphy and in telephony, the oscillations of the system will be kept at practically constant frequency by the vibrators,

making it possible, for example, to use a very high frequency, with all the advantages flowing therefrom. For example, consider a frequency of 50,000,000 cycles, corresponding to 6-meter wave length. A control of the frequency to within one tenth of one percent would obviously involve a difference in variation of 50,000 cycles. With a variation in frequency as great as 50,000 cycles, the signal is continually running off the setting of the receiving system, with the result that the operator has to shift continuously, trying to catch it here and catch it there. A part of the signal is detected, but a large part is often lost. According to the present invention, on the other hand, it is possible to maintain the frequency to within 1/100,000 of one percent. This involves a variation of only five cycles on a frequency of 50,000,000. Indeed, by proper care, it is possible to keep the variation within only one cycle.

The importance of this for beat reception will be realized when it is reflected that the local oscillator used for voice modulation may have a frequency of 1,000 cycles. A variation of 50,000 cycles or, for that matter, a variation of only 500 cycles, is a serious problem for beat reception under such circumstances. A variation of only five cycles, on the other hand, or, for that matter, as much as 50 cycles, could readily be handled.

These oscillations may also be employed, with or without amplification, to serve as sources in carrier-wave systems, or to aid in the receiving apparatus of a carrier-wave system. At the receiving station, the local oscillator will replace the suppressed carrier wave and this, with the received side band, will give the complete signal.

The vibrations of the electro-mechanical vibrator may also, in accordance with the present invention, be communicated to air or to some other elastic medium, as water, to produce sound for intercommunication or any other desired purposes.

The use of the Pierce oscillator,—as it is termed in the art,—in the present invention is particularly advantageous, because the system is always certain to oscillate at the frequency determined by the crystal, and at no other frequency. Using some crystal-controlled oscillators heretofore proposed, for example, a comparatively slight variation of comes entirely vitiated. The transmitting end, for example, may keep on transmitting without the operator knowing that, at the receiving end, it becomes necessary to shift and hunt for the signals, merely because the system at the transmitting end is oscillating without control by the crystal. This is impossible with the Pierce oscillator. The Pierce oscillator can not oscillate except with the aid of the crystal, and at any other than the crystal frequency. When the crystal is disconnected from the system, there are no oscillations. On the other hand, with the crystal in circuit, any variation in the parameters of the system, no matter how great, is automatically compensated for by the crystal itself. As the circuit is thus always under the control of the crystal, the frequency of its oscillations is always constant. Once the system starts oscillating, it is impossible for the frequency of the oscillations to drift out of control by variations in the parameters of the system, or for any other reason.

The Pierce oscillator,—crystal and all,—comprises a periodic system,—that is, a closed system in which any energy liberated in the system must swing periodically from the kinetic or motional form to the potential or stored form and back again, until dissipated. The period or frequency of these swings is a constant of the system, called its "natural frequency" or "natural period."

Other uses and applications and other modifications within the scope of the present invention will also readily occur to persons skilled in the art. It is therefore desired that the above-described embodiments of the invention shall be regarded as illustrative of the invention, and not restrictive, and that the appended claims shall be construed broadly, except insofar as it may be necessary to impose limitations in view of the prior art.

What is claimed is:

1. A transmitting and receiving system having, in combination, means for transmitting signal waves, means for receiving the signal waves, a local oscillating system comprising an amplifying relay having an inherent regenerative coupling, a source of energy, a piezo-electric body, and means connecting the relay, the source and the body together, the connecting means being such that the local system can not oscillate through the

riation of 50,000 cycles. With a variation in frequency as great as 50,000 cycles, the signal is continually running off the setting of the receiving system, with the result that the operator has to shift continuously, trying to catch it here and catch it there. A part of the signal is detected, but a large part is often lost. According to the present invention, on the other hand, it is possible to maintain the frequency to within 1/100,000 of one percent. This involves a variation of only five cycles on a frequency of 50,000,000. Indeed, by proper care, it is possible to keep the variation within only one cycle.

The importance of this for beat reception will be realized when it is reflected that the local oscillator used for voice modulation may have a frequency of 1,000 cycles. A variation of 50,000 cycles or, for that matter, a variation of only 500 cycles, is a serious problem for beat reception under such circumstances. A variation of only five cycles, on the other hand, or, for that matter, as much as 50 cycles, could readily be handled.

These oscillations may also be employed, with or without amplification, to serve as sources in carrier-wave systems, or to aid in the receiving apparatus of a carrier-wave system. At the receiving station, the local oscillator will replace the suppressed carrier wave and this, with the received side band, will give the complete signal.

The vibrations of the electro-mechanical vibrator may also, in accordance with the present invention, be communicated to air or to some other elastic medium, as water, to produce sound for intercommunication or any other desired purposes.

The use of the Pierce oscillator,—as it is termed in the art,—in the present invention is particularly advantageous, because the system is always certain to oscillate at the frequency determined by the crystal, and at no other frequency. Using some crystal-controlled oscillators heretofore proposed, for example, a comparatively slight variation of the circuit parameters, such as might be caused by running down of the battery voltage, will cause the system to oscillate at a frequency different from the crystal frequency, leaving the crystal inert and out of operation altogether. The circuits continue to oscillate, but at a different frequency from the crystal frequency. This happens without the operator even becoming aware of that fact. The system continues to oscillate without the crystal, and the operator's work be-

possible with the Pierce oscillator. The Pierce oscillator can not oscillate except with the aid of the crystal, and at any other than the crystal frequency. When the crystal is disconnected from the system, there are no oscillations. On the other hand, with the crystal in circuit, any variation in the parameters of the system, no matter how great, is automatically compensated for by the crystal itself. As the circuit is thus always under the control of the crystal, the frequency of its oscillations is always constant. Once the system starts oscillating, it is impossible for the frequency of the oscillations to drift out of control by variations in the parameters of the system, or for any other reason.

The Pierce oscillator,—crystal and all,—comprises a periodic system,—that is, a closed system in which any energy liberated in the system must swing periodically from the kinetic or motional form to the potential or stored form and back again, until dissipated. The period or frequency of these swings is a constant of the system, called its "natural frequency" or "natural period."

Other uses and applications and other modifications within the scope of the present invention will also readily occur to persons skilled in the art. It is therefore desired that the above-described embodiments of the invention shall be regarded as illustrative of the invention, and not restrictive, and that the appended claims shall be construed broadly, except insofar as it may be necessary to impose limitations in view of the prior art.

What is claimed is:

1. A transmitting and receiving system having, in combination, means for transmitting signal waves, means for receiving the signal waves, a local oscillating system comprising an amplifying relay having an inherent regenerative coupling, a source of energy, a piezo-electric body, and means connecting the relay, the source and the body together, the connecting means being such that the local system can not oscillate through the inherent regenerative coupling when the body is disconnected from the system, whereby the frequency of the waves of the local oscillating system is maintained substantially constant, and means for combining the received waves with the local waves.

2. A transmitting and receiving system having, in combination, means for transmitting signal waves, means for receiving the signal waves, each of the said means comprising a source of electric energy, a tube

having a plurality of electrodes, an electromechanical vibrator having two electric terminals respectively connected with two of the electrodes, means substantially non-periodically connecting the source, the tube, and the vibrator together to maintain the vibrator in vibration and the system in oscillation with a frequency widely independent of the electrical constants of the system and determined by a mode of mechanical vibration of the vibrator, the electrical parameters of the system being such that the system will not oscillate in the absence of the vibrator, the terminals being adapted to act conjointly both for electric stimulation and electric response to effect the oscillation of the system, and means for evidencing beats.

3. A transmitting-and-receiving system having, in combination, a transmitting system for transmitting electric waves, an electromechanical vibrator connected with the system for maintaining the frequency of the transmitting system substantially constant, the connections being such as to prevent the operation of the transmitting system at other than the said substantially constant frequency, a receiving system for receiving the electric waves, the receiving system being traversed by local oscillations, and an electro-mechanical vibrator connected with the receiving system for maintaining the frequency of the local oscillations substantially constant, the connections of the second-named electromechanical vibrator with the receiving system being such as to prevent the local oscillations at other than the second-named substantially constant frequency.

In testimony whereof, I have hereunto subscribed my name.

GEORGE W. PIERCE.

APPENDIX J

U. S. Patent No. 2,133,642, October 18, 1938

(See Pages 97 to 116 Opposite ☞)

97

Oct. 18, 1938. G. W. PIERCE 2,133,642

ELECTRICAL SYSTEM

Original Filed Feb. 25, 1924 3 Sheets-Sheet 1

Fig. 1

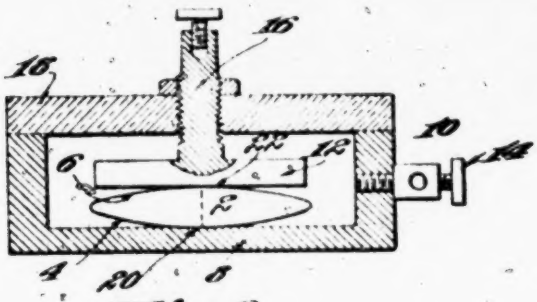


Fig. 2

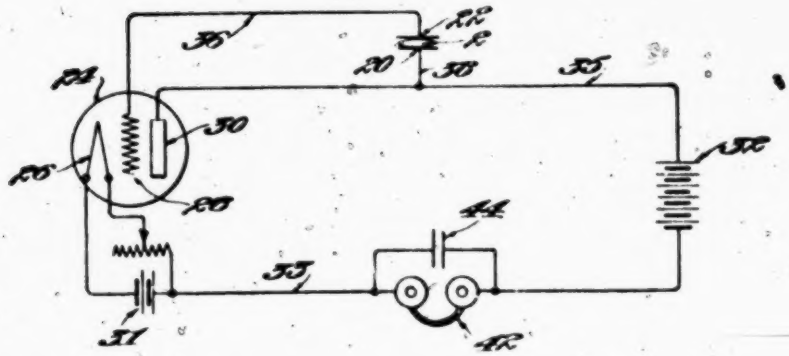
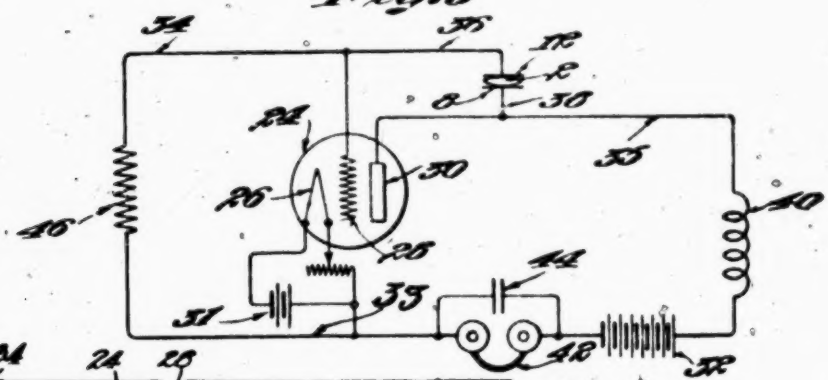


Fig. 3



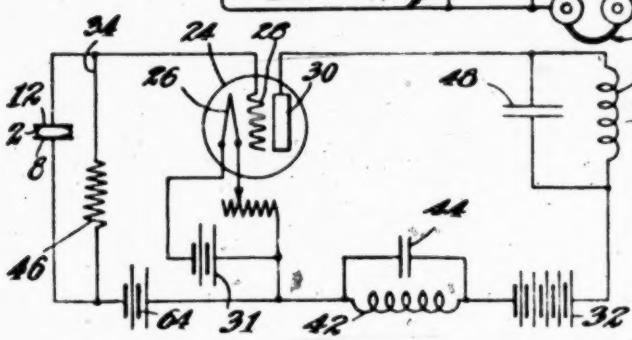


Fig. 11.

Inventor
George W. Pierce
By David Rines
Attorney

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Fig. 4

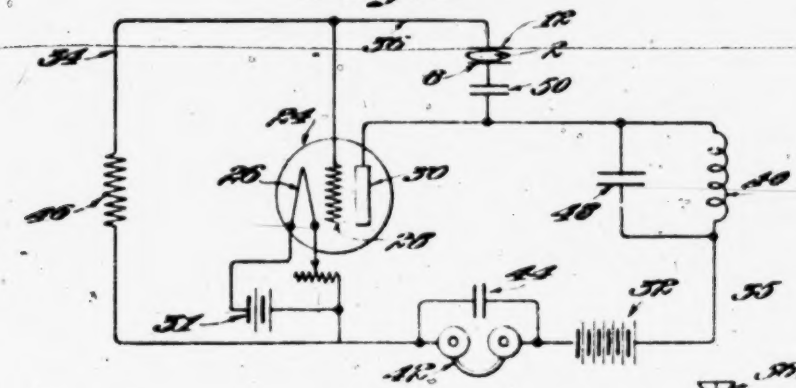


Fig. 5

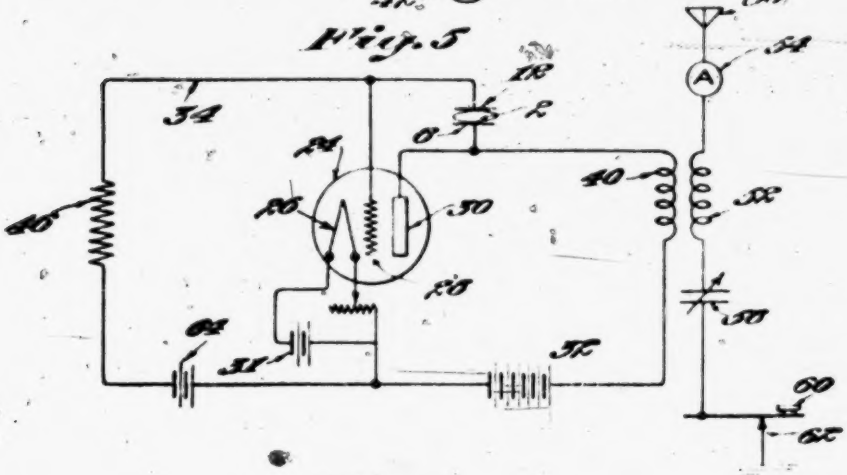
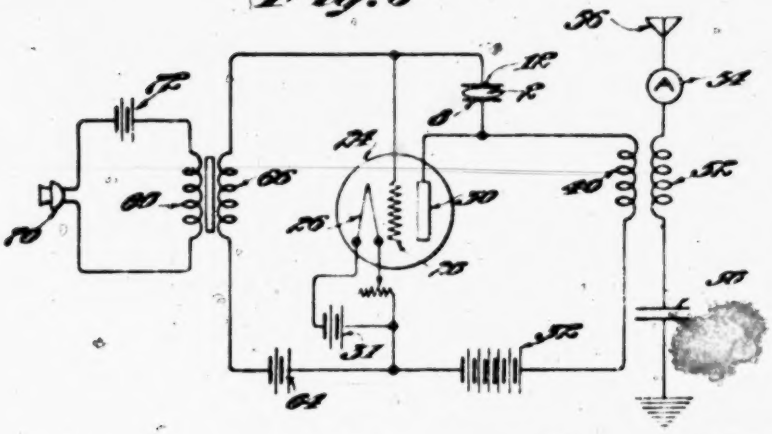


Fig. 6



Inventor
George W. Pierce
By David Rines
Attorney

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Fig. 7

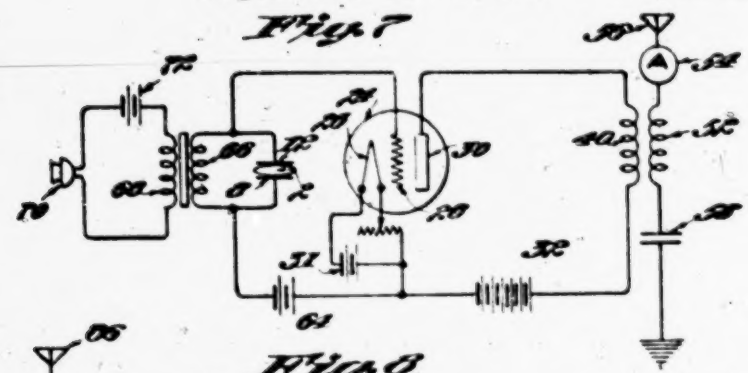


Fig. 8

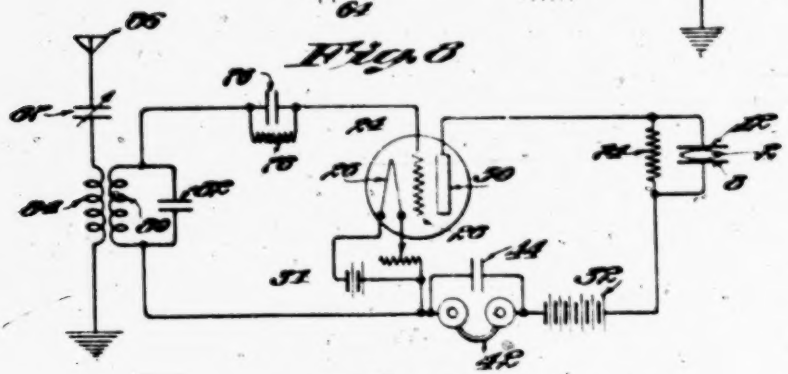


Fig. 9

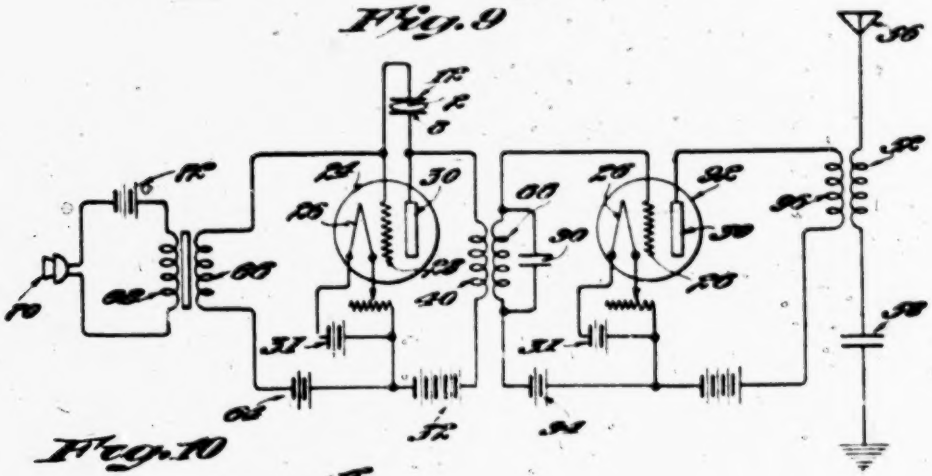
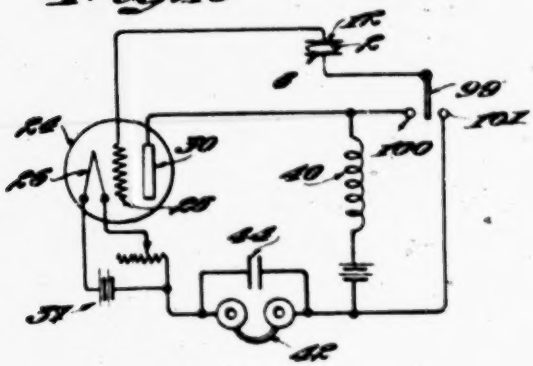


Fig. 10



Inventor
George W. Pierce
by Dann Rines
Attorney

UNITED STATES PATENT OFFICE

2,133,642

ELECTRICAL SYSTEM

George W. Pierce, Cambridge, Mass.

Application February 25, 1924, Serial No. 695,894
Renewed April 18, 1930

106 Claims. (Cl. 250—36)

The present invention relates to electrical systems, and more particularly to methods of and apparatus for producing and sustaining the oscillations of electrical and mechanical systems. From a more limited aspect, the invention relates to systems that employ the inter-action of an electro-mechanical vibrator and an electric circuit to generate electrical and mechanical oscillations.

Electro-mechanical vibrators of the above-described character have the property of executing mechanical vibrations under vibratory electrical stimulus; and, conversely, of developing electrical potentials as a result of their mechanical vibrations. Piezo-electric bodies,—such as a whole crystal or part of a crystal of quartz, Rochelle salt, tourmaline, and the like,—have long been known to possess this property. Such bodies possess at least one, and usually two or more, axes—known as the electrical axes of the body—that have definite orientations in the original crystal. When a potential gradient, with a component in the direction of an electric axis, is applied to such a crystal body, the body undergoes mechanical deformations; and conversely, when the crystal body is deformed, a potential gradient is established in the body. The crystal body is, in general, capable of two or more particular modes of mechanical vibration, of different frequency, that correspond to two or more of its dimensions. These mechanical and electrical effects are normally transitory, for the crystal body will not, of itself, persist in continuous vibration.

An object of the present invention is to provide a novel method of, and a novel system and novel apparatus for, rendering these effects oscillatory in character, and persistent.

A further object is to provide an improved method of, and improved apparatus for, producing oscillations at very nearly constant frequency.

Another object is to improve the efficiency of oscillatory systems.

Another object is to obviate interference in oscillatory systems.

With these ends in view, a feature of the invention resides in a novel electrical system comprising an electric circuit that is not, in itself, oscillatory, and that is not, in itself, a source of alternating currents, in combination with an electro-mechanical vibrator that will not, in itself, persist in continuous vibration; the electrical parameters or constants of the system being such as to render the system stably non-oscillatory when not under the control of the electro-mechanical vibrator; and the connections being such, however, that the resulting electrical system oscillates at a frequency determined, to a high degree of precision, by the frequency of one of the modes of mechanical vibration of the electro-mechanical body; and the frequency being essentially unmodifiable, even by large changes of the electric constants of the circuits of the system, except in cases where certain controllable changes, as hereinafter stated, may result in shifting the frequency from that of one mode to that of another distinct mode. In the preferred forms of the present invention, the disturbing effects,—such as those produced by changes of temperature, changes of mounting supports, changes of electrical constants, and the like,—on the frequency of oscillations usually amount to less than one one-hundredth of one per cent of the frequency. These small effects are nevertheless well under control, in the present invention, and are themselves utilized to introduce useful minute variations of frequency, when desired. It is believed that the present invention provides, over a wide range of frequencies, and particularly at high frequencies, a source of electrical and mechanical oscillations of frequency more constant and more stable than any heretofore known.

Since the electro-mechanical vibrator is, in general, capable of two or more modes of vibration, of different frequencies, the present invention provides means for changing at will from one mode to another; and, in some cases, for the utilization of two or more frequencies coexistent at the same time, in the same system.

Piezo-electric crystals are usually provided with terminals or electrodes. It is by means of these electrodes that the crystal is adapted to be connected in an electric circuit. It has hitherto been proposed to provide two pairs of electrodes to adapt the crystal for use in an oscillatory system,—one pair to be connected with the input terminals of an amplifying device, and the other pair to be connected with the output terminals. The theory of the operation is that the energy of the vibrating crystal will be transferred from the output terminals to the input terminals. A similar proposal has been made for systems comprising electrically driven tuning forks. These proposals are not, however, adapted for high frequencies; since, for high frequencies, the mechanical vibrator becomes of such small dimensions that there is not room for two pairs of electrodes or two pairs of magnets of sufficient size to operate the device, and at the same time avoid

the electrical feed-back that produces vibrations independent of the mechanical system, and lacking in the desired constancy. The proposed multiple-paired piezo-electric oscillator, furthermore, depends for its operation upon the lengthwise period of vibration of the crystal body; whereas, for high frequencies, it is necessary to use the period of the crystal vibrations determined by a dimension of the specimen which is small compared with its other dimensions, as by its thickness, the crystal plate vibrating in its thickness mode, and this must be of the order of one millimeter for a frequency of 3000 kilocycles per second. Such high frequency is obviously unattainable with a multiple-paired piezo-electric oscillator.

It is therefore still another object of the present invention to improve upon and simplify the apparatus employed in, and the electrical connections of, oscillatory systems.

To this end, a feature of the invention contemplates the use, in general, of but a single pair of active, electrical terminals or electrodes applied to the electro-mechanical vibrator. The apparatus of the present invention may therefore be equally well employed at high, as at low, frequencies. I have constructed apparatus, according to the present invention, for fundamental frequencies ranging from 35 kilocycles per second to 3,000 kilocycles per second. I have utilized harmonics of the device at frequencies of 20,000 kilocycles per second, corresponding to an electric wave of fifteen meters wave length. This range may undoubtedly be extended in both directions.

Other and further objects of the invention will be explained hereinafter, and will be pointed out in the appended claims, it being understood that it is intended to cover in the appended claims all the novelty that the invention may possess.

In the accompanying drawings, Fig. 1 is a sectional view of an electro-mechanical vibrator of preferred form, comprising a piezo-electric body provided with electrodes; Fig. 2 is a diagram of circuits and apparatus illustrating an operable embodiment of the invention; Fig. 3 is a similar diagram with additional elements; Fig. 4 is a view similar to Fig. 3, with still further additional elements, one of which is electrically tunable; Fig. 5 represents a radio-telegraphic transmitting apparatus embodying the invention; Fig. 6 represents a radio-telephonic transmitting apparatus; Fig. 7 is a modified transmitting apparatus; Fig. 8 represents an embodiment of the invention in a receiving system for beat reception; Fig. 9 is a radio-telephonic transmitter using power amplification and embodying the invention; Fig. 10 is a diagrammatic view illustrating a means for changing the frequency by changing the mode of vibration of the electro-mechanical vibrator, which is effected by switching a circuit connection; and Fig. 11 is a diagram illustrating a further modification.

All of the figures, except Fig. 1, show the employment of the electro-mechanical vibrator as the means for determining the wave frequency. This electro-mechanical vibrator is differently disposed in the different diagrams, so as to illustrate the many different ways in which the vibrator may be employed to introduce oscillations into the system, but it is to be understood that the electro-mechanical-vibrator disposition, in a particular diagram, is not specific to that diagram, but that the vibrator may be similarly disposed in the other diagrams.

It will conduce to an understanding of the invention to describe, first, a preferred form of electro-mechanical vibrator, which, in Fig. 1, is illustrated as of the piezo-electric type. The invention is not, however, in its broader aspects, limited to such a crystal body, but may employ any body or mechanism having like properties in itself, or like properties introduced by electric currents, electric polarization, magnetic fields, etc. At 2 is shown a piezo-electric body, which has one of its electrical axes in the direction of the thickness of the crystal plate, along the line 20—22. I have found many different shapes of piezo-electric crystal body to be operative, such as a parallelopiped or a flat disc, but for many purposes, I prefer that the piezo-electric body and its electrodes be, the one or the other, slightly curved, to diminish friction or clamping between the body and its electrodes. I have hence illustrated the piezo-electric body as lenticular in shape. It may be constituted of any suitable substance having sufficiently pronounced piezo-electric properties. Quartz is preferred, because of its durability and constancy. Though the preferred shape of crystal element constitutes a feature of the present invention, it will be understood that many features, hereinafter described, are not restricted to the use of any particular substance or any particular shape. The term "electro-mechanical vibrator"—or, more simply, the term "vibrator"—will therefore be employed hereinafter, in the specification and the claims, to denote any substance, material or arrangement, whether or not crystalline in character, that is endowed with the above-referred-to property of changing shape or dimensions under the action of an electric force or an electric current and of reacting on the electric circuits.

The oppositely disposed, convex surfaces of the lenticular plate 2 are indicated at 4 and 6. The surface 4 is shown contacting with, or slightly separated from, the bottom 8 of a box, receptacle or housing 10 that is constituted of a conducting material, as a metal, and the surface 6 contacts with or is near to a second conducting member 12. The bottom 8 and the member 12 constitute the opposed electrodes, terminals or plates of the crystal. The electrode 8 is electrically connected to a binding post 14 and the plate 12 is electrically connected to a binding post 16. Electrical connection is thus established between the two sides 4 and 6 of the crystal and the terminal binding posts exterior of the box or housing 10. The binding post 14 is simply secured to a side of the box 10. The binding post 16 is threaded through an insulating cover 18 of the box 10, and is secured to the plate 12. The cover 18 may be constituted of hard rubber. By screwing the binding post 16 in one direction or the other, the plate 12 may be caused to approach the crystal 2 more or less nearly, as desired. Owing to the fact that the surfaces 6 and 4 are convex, the plates 8 and 12 approximate or touch the crystal at two oppositely disposed points, or small areas, indicated at 20 and 22, thus allowing for expansion or contraction with small friction or obstruction. The preferred form of electro-mechanical vibrator is thus illustrated as a two-electrode piezo-electric crystal plate 2, adjacent to the oppositely disposed sides or surfaces 4 and 6 of which are provided the two opposed conducting electrodes, terminals or plates 8 and 12 by means of which the vibrator is adapted to be connected in an electric circuit. Such a crystal plate is sometimes termed a piezo-electric resonator.

When the crystal body 2 assumes the form of a parallelopiped or a flat disc, its lower flat surface 4 may be horizontally disposed in contact with the upper flat surface of the electrode 8, and the electrode 12 is spaced slightly above its upper flat surface 6, with the electrodes 8 and 12 disposed substantially perpendicular to the electric axis 20, 22 of the crystal. In order to exhibit its piezo-electric properties, electrical connection with the upper surface 6 of the crystal 2 may be established through the electrode 12, and with the lower flat surface 4 of the crystal 2 through the electrode 8, into any electric circuit. The crystal 2 is thus substantially horizontally supported between and adjacent to the lower substantially horizontally disposed substantially flat surface of the upper electrode 12 and the upper substantially horizontally disposed substantially flat surface of the lower electrode 8, with its oppositely disposed substantially flat upper and lower faces 4 and 6 substantially horizontally disposed respectively adjacent and substantially parallel to the respective substantially flat surfaces of the electrodes.

The preferred form of electromechanical vibrator having thus been described, reference may now be had to Fig. 2 for an embodiment operable according to the present invention. For illustrative purposes, a hermetically sealed multi-electrode electron or electron-discharge vacuum tube container 24 is diagrammatically shown provided with three sensitive elements or electrodes, namely, an electron-emitting cathode filament 26, a first cold electrode, shown as a control grid 28, and a second cold electrode, shown as a plate or anode 30. The vacuum tube 24 may constitute an amplifying relay. As illustrated, the cold electrodes 28 and 30 are unequally spaced from the cathode 26, the electrode 28 being the inner cold electrode and the electrode 30 being the outer cold electrode. The control electrode or grid 28 controls the transmission of current between the cathode 26 and the anode 30.

The invention is not restricted to the use of this particular type of tube, but it will serve for illustrative purposes; it being understood, however, that the terms "plate" or "anode" and "grid", as used herein, will include within their scope other sensitive elements of different types of tubes, and that the term "filament" or "cathode" will be employed, in the specification and the claims, to include any suitable means for rendering the space of the tube conducting,—exemplified in the drawings by the filament proper 26 connected to the filament-heating battery 31. The vacuum tube is provided with a grid or input circuit interconnecting or including the grid 28 and the cathode 26, and an anode or plate or output circuit interconnecting or including the cathode 26 and the plate 30. The plate and the grid circuits are shown in Figs. 7 and 8 substantially mechanically and electrically disassociated from each other except for the association introduced or caused by the electron stream between the plate and the cathode within the electron-tube container 24. Substantially all the regeneration of the regenerative oscillatory system thus produced is effected through capacitive coupling between the grid 28 and the anode 30. A plate battery 32 is connected to the filament 26 by a conductor 33, and to the plate 30 by a conductor 35. The plate battery 32 constitutes a source of energy for charging the plate 30 with a unidirectional suitable operating potential. A telephone receiver 42, with or without a bypass condenser 44, may be inserted in the conductor 33. As so far described, the system is not oscillatory. If, now, one of the electrodes of an electro-mechanical vibrator, such as that of Fig. 1, be connected by a conductor 36 to the grid, and the other electrode by a conductor 38 to some point in the circuit of the plate 30, the system will oscillate with sustained oscillations and the vibrator will vibrate mechanically, at a frequency determined, to a high degree of precision, by the frequency of one of the modes of mechanical vibration of the electro-mechanical vibrator. The mode of vibration depends somewhat on the point of connection to the plate circuit. This is explained below. A system originally not oscillatory, in the absence of the vibrator, is thus rendered oscillatory, when the vibrator is connected into circuit with a fixed period of oscillation determined by the frequency of some mode of vibration of the vibrator, and the oscillations will continue as long as the circuits and the energy-supplying batteries remain intact.

The utility of the present invention is not, of course, dependent upon the existence or the non-existence of theories, whether accurate or inaccurate, to account for the observed phenomena. It is sufficient to describe and illustrate the invention as it has been found to work in practice. The theory of operation is, however, probably as follows: First, a circuit is established from the battery 32, by way of the conductors 35 and 38, to the vibrator 2, and from the vibrator 2, by way of the conductor 36 to the grid 28. The vibrator is thus stimulated and commences to vibrate. In so vibrating, it reacts upon the current in the circuit thus established, and, incidentally, affects the potential of the grid 28. The potential of the grid 28 is alternately increased and decreased many times a second, corresponding to the natural frequency of mechanical vibration of the vibrator. These potential variations of the grid therefore affect the current flowing from the battery 32 through the tube 24, resulting in the establishment of oscillations in the circuit extending from the battery 32, by way of the conductor 35, to the plate 30, through the ionized space in the tube, to the filament 26 and by way of the conductor 33, back to the battery 32. The oscillations of this circuit, in turn, act to stimulate the vibrator to maintain it in vibration and the vibrator, in its turn, responds to maintain the system in oscillation with a fixed period determined by the vibrator. When the telephone 42 is not needed, it may be replaced by an inductance, as illustrated in Fig. 11, the primary winding of a transformer, or the input terminals of an amplifier, or it may be wholly short-circuited.

In the specification and the claims, the action of the electric forces that cause mechanical displacements of the crystal, resulting in its vibration, will be termed "stimulation"; and the development by the vibrating crystal of the electromotive forces that react upon the circuit will be termed "response".

Fig. 3 resembles Fig. 2. An element 40, shown as an inductance coil having a distributive capacity and resistance, is, however, connected in the output or plate circuit, between the battery 32 and the conductor 35. The coil 40, which acts as an admittance, may be replaced by a resistor or any other proper type of electrical apparatus or elements, tuned or untuned, in which the oscil-

latory power is utilized. If a resistor 40 is employed, its distributive capacity and the capacity between the electrodes of the tube supply the parameters having the requisite values for determining the oscillating condition, as will be understood from the description to follow.

Fig. 3 also shows a connection 34 having an impedance element 46 connected in the grid or input circuit. This may be used to give the grid a suitable potential about which its fluctuations occur.

A space-discharge oscillation generator is thus produced, the oscillating frequency of which is dependent merely on the physical dimensions and properties of the crystal 2, and is substantially independent of the electrical parameters of the circuits.

A tuning condenser 48 may be connected in parallel with the coil 40, in the output circuit, external to the input circuit, and may be employed to control the amplitude of the current fed back from the output circuit to the input circuit, and stabilized as to frequency in accordance with the natural period of the piezo-electric device. The parallel-connected tuning-condenser capacity 48 and inductance 40 constitute a tunable resonant circuit connected in the output circuit of the tube. Other elements resonant to a frequency widely different from the oscillation frequency may also be used. The power of the system may, for some purposes, be increased by electrical tuning of some other element into or near resonance with the frequency of the mechanical vibrations of the vibrator. Such tuning makes it possible to exclude undesired frequencies. To understand what is meant by the term "tuning", it will be recalled that, when a circuit exhibits inductive reactance for one band of frequencies, capacitive reactance for a second band of frequencies, and zero reactance for a particular frequency between these two bands, the circuit is said to be "tuned" or "resonant" at the said particular frequency. Alternatively, this may be stated in terms of the phase relations between the voltage across the circuit and the current through the circuit. When, at any particular frequency, a circuit that exhibits reactance at other frequencies exhibits an impedance that is a pure resistance at the said particular frequency, so that the said current and the said voltage are in phase, that circuit is said to be tuned or resonant at the said particular frequency.

Assuming the parameters of the circuit to be properly chosen to produce crystal-controlled oscillations, as by approximate adjustment of the various elements of the system, the system will oscillate with a frequency determined by the frequency of some resonant mode of mechanical vibration of the electromechanical vibrator; that is, the parameters of the system will have electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency that is stabilized and determined by some mode of mechanical vibration of the vibrator substantially independent of the value or the nature of the element 40, and such as to render the system stably non-oscillatory when not under the control of the vibrator. The electrodes 8 and 12 act conjointly both for stimulation and response, the vibrator being stimulated by the oscillations so as to be maintained in vibration, and responding to maintain the system in oscillation, with a fixed period determined by the vibrator.

The stably non-oscillatory circuit of the present invention is to be contrasted with the circuits described, for example, in the patent to Cady, 1,472,583, page 2, lines 110 and 111 and page 3, line 73, which are so loosely coupled as to be on the border line between oscillatory and non-oscillatory. The coupling is so loose that the circuit is on the very verge of oscillating, yet does not do so; as the Cady patent describes it, the circuit "just fails" to oscillate. Slight fortuitous plate or cathode voltage changes, or other changes of the circuit parameters or constants, are continuously being introduced, in practice. These may be caused, for example, by accidental changes of a condenser (as when it becomes aged), an inductance, or a tube characteristic (as when the tube deteriorates, or becomes replaced by another tube); or by a slight running down of a battery, or a change in the inductance or the capacity of a coil caused by vibration or heating, or even a change in temperature. Changes of this character may readily throw the said border-line system into a condition that is oscillatory without the crystal, the oscillations so produced being of any frequency determined by the electrical parameters of the system itself, and independent of the vibrations of the crystal, just as though the crystal were not present. Such changes have no observable effect, however, upon the stably non-oscillatory system of the present invention. The crystal constitutes an essential element of the system; without the crystal, the system can not oscillate under any conditions. As the oscillations are thus always determined by the crystal, they are necessarily constant and unmodifiable always, even though wide changes of the electric parameters or constants are introduced. Parasitic oscillations are inhibited. The system of the present invention, in other words, is stably non-oscillatory in the absence of the crystal.

An easy way of selecting suitable circuit parameters for oscillation controlled by any vibrational mode of the crystal is to tune the circuit elements. For example, the plate or output circuit of the tube 24 may be adjusted by means of the condenser 48, so as to obtain high-current output. Due to the action of the crystal in maintaining constant the oscillation frequency, such adjustments are not critical; oscillations will be generated for a wide range of values of the condenser 48 or of the coil 40. Alternatively, the coil 40 may be so chosen as to have suitable resonant properties without the use of a discrete condenser 48. In attempting to obtain oscillations, of course, one would always select proper parameters; and tuning the circuits by means of the condenser 48 is one way of obtaining such proper parameters.

An impedance, shown as a condenser 50, may be inserted between the plate 30 and the grid 28, in series with the vibrator, as is also illustrated in Fig. 4, to relieve the voltage on the vibrator, though the condenser 50 is by no means necessary.

A radio-telegraphic transmitting apparatus according to the present invention is illustrated in Fig. 5. The coil 40 is coupled to a coil 52 in the usual manner. The coil 52 is connected, in series with a hot-wire ammeter 54, to an antenna 56, and through a tuning condenser 58, to a sending key 60. The key 60 is adapted to make and break contact with a grounded contact member 62. The coils 40 and 52 are so adjusted as to tune the system for the maximum current, as observable in the ammeter 54. The method of

telegraphing will be obvious to persons skilled in the art, and need not be further described.

If desired, a biasing battery 64 may be employed to bias the grid 28, the battery 64 constituting a means for charging the grid 28 with a different predetermined unidirectional suitable operating potential, as is also illustrated in Fig. 5. The potential of the grid will then fluctuate about the biased value, with a frequency determined by the mechanical vibrations of the vibrator.

The biasing battery 64 may be chosen of such voltage as to permit oscillations to be produced. In a circuit of the illustrated character, this bias will usually be negative, so as to polarize the grid 28 negatively with respect to the cathode 26. The battery 32, on the other hand, will subject the anode 30 to a positive potential with respect to the cathode 26.

For telegraphing or telephoning over line wires it is evident that the antenna circuit of the various figures may be replaced by well-known connections to the line wires. The same remark applies to reception along line wires as alternative to reception by an antenna.

For telephoning in accordance with the present invention, the connections shown in Fig. 6 may be employed. The impedance element 46 here takes the form of the secondary winding 66 of a modulation transformer, and the tuning condenser 58 is shown connected to the ground. The primary winding 68 of the transformer may be connected to a microphone 70, in circuit with a source of energy, shown as a battery 72. The grid will now be subjected to fluctuations of voltage caused not only by the vibration of the electro-mechanical vibrator, but also by the microphone. The variations produced by the microphone will modulate the carrier oscillations of the system. The operation will be understood by persons skilled in the art without further description.

Both in telegraphy and in telephony, as described in connection with Figs. 5 and 6, the oscillations of the system will be kept at practically constant frequency by the vibrator, making it possible, for example, to use a very high frequency, with all the advantages flowing therefrom.

In all the illustrations so far described, the electro-mechanical vibrator has been inserted between the grid and the plate of the vacuum tube. This arrangement is by no means essential. The vibrator is inserted in the system of Figs. 7 and 11 in the input grid circuit, between the filament and the grid; and in that of Fig. 8, in the plate circuit, between the filament and the plate. The winding 40 of Fig. 7 acts as an admittance. The word "admittance", which is quantitatively the reciprocal of an impedance, is herein used to designate an electrical circuit element or combination of elements, looked at with reference to its facility for passing current under a given electromotive force. The hereinaftermentioned winding 80 and condenser 82, for example, constitute an admittance. A piezo-electric crystal provided with electrodes also constitutes an admittance. In general, if any electric system is provided with two oscillation circuits, each, for example, having a condenser in parallel with an inductance, one of the two circuits may be replaced, according to the present invention, by the electro-mechanical vibrator, and the oscillations of the resulting system, when established, will be of the frequency of the vibrator and highly constant.

Electric circuits have heretofore been produced with parameters having electrical characteristics such as to render the system stably non-oscillatory in the absence of a tuned element of the system and such as to render the system oscillatory when the tuned element is connected with the system. One of the prior-art circuits, for example, comprised a tuned element in the grid circuit and another tuned element in the plate circuit, the grid and plate circuits being uncoupled except for the capacity coupling between the grid and the plate. Such circuits, as is well known, will not oscillate unless proper circuit elements are chosen. In the oscillator herein shown, one of the said tuned elements of the prior art may be replaced by the electromechanical vibrator in the grid circuit, for example, as illustrated in the drawings. As in the case of the prior-art circuits, oscillations will or will not be produced, depending upon whether proper circuit elements have been chosen; but when oscillations are established, they will be of the frequency of the vibrator and highly constant.

In the system of Fig. 7, the two-electrode crystal, being disposed in the input circuit only, forms the only path between the grid and the cathode in which high-frequency currents of the order of magnitude of a natural frequency of the crystal cause resonance effects. This input circuit is substantially untuned for the frequency of oscillation, except through the crystal. A path for direct current is afforded by the coil 66, which coil 66 acts as a leakage path from the grid 28 to the cathode 26 to choke back currents of the frequency of the oscillations and prevents the crystal oscillating voltage from passing substantially beyond the zero grid voltage and becoming a positive voltage.

In Figs. 2 to 6 and Fig. 7, the crystal is connected in a control circuit. In the one case, the control circuit is between the control grid electrode 28 and the anode electrode 30; and in the other, between the control grid electrode 28 and the cathode electrode 26.

Turning first to Fig. 7, the connections are very much as in Fig. 6, except that the grid 28 and the plate 30 are no longer connected by the electro-mechanical vibrator. The vibrator is, instead, connected in parallel to the winding 66 of the modulation transformer, which winding may, indeed, be replaced by a resistor of high resistance with a new disposition of the microphone. Corresponding connections for transmitting by telegraph, or for receiving, will be obvious to those skilled in the art.

A receiving system is illustrated in Fig. 8. The vibrator is shown inserted in the plate circuit, between the plate and the filament, and is shown effectively connected in parallel with, or shunted by that portion of the plate circuit that is illustrated as a bypass 74 for direct current. The bypass 74 may be a radio choke, an inductance coil or winding, a resistor, or a combination of these. The bypass 74 is preferably so chosen that the circuits shall have parameters such as to make the system stably non-oscillatory when the crystal is removed or restrained from vibration. A blocking condenser 76, shunted by a leak resistor 78, and a winding or inductance coil 80, shunted by a tuning condenser 82, to render the grid circuit tunable, are connected in the grid circuit, between the filament and the grid.

If the parameters of the circuits are properly chosen, as by approximate adjustment of the condenser 82, continuous oscillations will be set up in the system at a frequency determined by that mode of vibration of the vibrator corresponding to a natural or resonant frequency of the crystal in the direction of its electric axis, though it will not oscillate in the absence of the crystal. The system will oscillate even though the parameters be varied to within very wide limits, and the frequency will be maintained constant irrespective of variations in plate or filament voltage, load or other factors. This is not true of self-oscillating circuits in which the crystal acts merely as stabilizer. In the latter case, variation in the parameters of the circuit will result in the crystal ceasing to vibrate, though the circuits continue to oscillate. The system can be used as an oscillatory circuit.

As the system of Fig. 8 is illustrated as employed in a receiving circuit, the winding 80, which here replaces the impedance element 46, is shown coupled to a winding 84, in series with a receiving antenna 86 and a condenser 87, and grounded or connected to a counterpoise. The antenna 86 will receive the radio signals transmitted from the antenna 56, which will be detected by the telephone receiver 42.

The locally generated oscillations of the circuits of the tube 24 will beat with the oscillations received by the antenna 86, according to well-known principles, rendering the received signals audible in the telephone 42, or giving them any required superaudible frequency, for superheterodyne reception. These locally generated oscillations may also be employed to supply a suppressed carrier frequency if desired.

A system of this character is adapted to receive high-frequency radiations, to which the electrical tuning elements are adjusted, and to superimpose upon them the frequency of mechanical vibration of the vibrator. The two frequencies are thus coexistent at the same time, permitting beats to be produced.

A tunable transmitting system, such, for example, as is illustrated in Fig. 9, and a tunable receiving system, such as is illustrated in Fig. 8, each supplied with a suitable vibrator, may, the one transmit, and the other receive, constant oscillations of very high frequency. This has been done by me over considerable distances. The constancy of the beat note and the consequent certainty of being always in adjustment to receive the given signals was found to be of great value, rendering possible the use of very high frequencies. If the vibrators at the sending and the receiving stations are of sufficiently different frequency, a fixed, superaudible beat will be produced, adapted for apparatus of the superheterodyne type.

The invention is readily adapted to power-amplifying systems; and one such system, adapted for transmission, is illustrated in Fig. 9. The connections are very much as in the transmitting system of Fig. 6, except that the winding 48, instead of being directly coupled to the winding 52 of the antenna circuit, is shown coupled or interlinked with a winding 88 that is shunted by a tuning condenser 90. The winding 88 is connected in the grid circuit of a second vacuum tube 92, biased by a battery 94. The winding 96 is connected in the plate circuit of the vacuum tube 92, and is coupled to the radiating antenna 56 through the antenna coil 52. The vibrator 2 determines the frequency of oscillation of the master oscillating circuit comprising the vacuum tube 24. The master oscillator, which may be of, say, 5 watts, controls, through power amplification, the tube 92 of much higher power, say 50 watts, and so forth. Such a system has been successfully operated by me in practice over a considerable distance. Any desired number of such amplifying units may be interposed in cascade without in any way departing from the present invention.

Fig. 10 illustrates a method of changing the mode of vibration of the electromechanical vibrator. As an example, I have found that, with an electromechanical vibrator having one electrode 12 connected to the grid and the other electrode 8 connected to the plate, as before described, the vibrator having in series with it an inductance coil of, say, 10 millihenries to 125 millihenries inductance, as described in my hereinafter-mentioned paper, the vibrator oscillates with a stable, highly constant frequency determined by the period of the vibrator along its electrical axis, the crystal vibrating in the direction of its thickness. This normally occurs when the switch arm 99 of Fig. 10 is in contact with the switch point 100 and corresponds, say, to the connections of Fig. 3. If, now, the switch arm 99 is shifted to the switch point 101, the same vibrator, being now connected, through the capacity 44, with the filament 26, corresponding, say, to the connections of Figs. 7 and 11, oscillates normally with a new stable frequency determined by a dimension at right angles to the said electrical axis. Since this dimension at right angles to the electrical axis is, in general, different from the dimension along the said axis, the shift of the switch arm 99 changes the oscillations from one stable frequency to another stable frequency. It is thus possible, in general, to obtain different frequencies, depending upon whether the crystal is connected between the filament and the grid or between the grid and a point in the plate circuit.

The prime reason for the different frequency vibrations will be made apparent when it is remembered that the frequency of the oscillations of an oscillating circuit depends upon the electrical parameters of the circuit. The crystal has capacitance, inductance and resistance of variable character, and these vary so as to have different effective values in accordance with the connections of the crystal between the electrodes of the vacuum tube. When the crystal is disposed between the grid and the filament, as in Figs. 7 and 11, it cooperates with the impedance of the rest of the system in such fashion that the resultant electrical parameters are of such values as to produce oscillations determined by one mode of vibration of the crystal. When the crystal is connected between the grid and the plate, as in Fig. 3, on the other hand, the resultant electrical parameters will be of such value that the oscillations will be determined by another mode of crystal vibration.

It is possible to obtain different frequencies first: by using the same coil 48 or other apparatus, and a different crystal; secondly, by using different coils 48 or other apparatus, and the same crystal; thirdly, by varying both the crystal and the other electrical apparatus; and finally, by connecting the crystal into the system in different ways, as before described.

It may be remembered that, in Fig. 3, for example, when the resultant effective impedances of the grid and the plate circuits are inductive,

the resultant impedance of the crystal vibrator is capacitative; and where the resultant impedances of the grid and the plate circuits are capacitative, the resultant impedance of the crystal is inductive. When the crystal is connected between the grid 28 and the cathode 26, for predetermining the potential variation of the grid 28, as another illustration, the resonant means in the plate or output or anode circuit of the tube has an inductive reactance for the natural frequency of the crystal, or is tuned to a higher frequency than the said predetermined frequency, which is one of the natural frequencies of the crystal. The reactance of the choke coil 66 and of the crystal electrodes and of the capacity between the anode 30 and the cathode 26 is, therefore, such as to resonate at a frequency substantially less than the frequency at which the crystal is caused to operate. The voltages generated by the vibrations of the crystal between the grid 28 and the cathode 26 of the tube can produce oscillations only when the output circuit is adjusted so as to have the said inductive reactance. In all cases, the output circuit is tuned to a frequency approximately that of the said natural frequency. When the crystal is connected between the grid 28 and the cathode 26, the voltage across the output circuit is impressed upon the crystal through the capacity path between the grid 28 and the anode 30. When the crystal is connected between the grid 28 and the anode 30, the voltage across the output circuit may be impressed upon the crystal through the capacity path between the grid and the filament.

The piezo-electric-crystal-controlled oscillating circuit illustrated in Fig. 11 is based upon the circuit of Fig. 4 or Fig. 5, but with the crystal 2 shown between the filament 26 and the grid 28, instead of between the grid 28 and the plate 30 of the vacuum tube 24. This different disposal of the crystal may be obtained merely by moving the switch arm 99 of Fig. 10 into contact with the switch point 101, instead of the switch point 100. The reference numerals of Fig. 11 represent the same elements as heretofore described. The pair 8 and 12 of metal contact plates on each side of the crystal 2 are connected, respectively, to the filament 26 and the grid 28. The negative terminal of the source of potential 64 is connected to one end of the impedance element 46, and its positive terminal is connected direct to the filament 26, through a variable, filament-regulating rheostat. The impedance element 46 is so arranged that its opposite terminal is connected to the grid 28. The impedance element 46 may, for example, be a choke coil. The input circuit of Fig. 11, therefore, corresponds to the input circuit of the modulated, radio sending or transmitting system illustrated in Fig. 7, which, as before stated, may be used for receiving, by obvious changes, as illustrated in Fig. 4. The output, or plate oscillating, system corresponds to the output circuit of the said Fig. 4, and comprises the plate 30, the choke coil 42, the radio-frequency by-pass condenser 44, which bridges the choke coil 42 to afford a path for high-frequency currents that are choked by the choke coil 42, the high-potential source 32, and a resonant circuit consisting of the inductance 40, together with its distributive resistance, and the capacity 48.

I have also found that very minute variations of frequency of the order of one three-hundredth of one per cent may be introduced by bringing the electrodes more or less near to the piezo-electric vibrator. This is of importance in the final adjustment of such a vibrator, where extreme precision of frequency is required.

The invention may be applied also to many other uses. The oscillations, together with their harmonics, may, for example, serve as fixed values for the calibration of wavemeters and frequency meters, as is explained in a paper by me, entitled "Piezoelectric crystal resonators and crystal oscillators applied to the precision calibration of wavemeters" published in the "Proceedings of the American Academy of Arts and Sciences", vol. 59, No. 4, October, 1923.

These oscillators may also be employed with or without amplification to serve as sources in carrier wave systems.

The vibrations of the electro-mechanical vibrator may, in accordance with the present invention, be communicated to air or to some other elastic medium, as water, to produce sound for intercommunication or any other desired purposes.

Other uses and applications and other modifications within the scope of the present invention will readily occur to persons skilled in the art. It is therefore desired that the above-described embodiments of the invention shall be regarded as illustrative of the invention, and not restrictive, and that the appended claims be construed broadly, except insofar as it may be necessary to impose limitations in view of the prior art.

I claim:

1. An electro-mechanical system having, in combination, a vacuum tube, a grid circuit and a plate circuit through said tube, an electro-mechanical vibrator having two electrodes serving conjointly both for stimulation and response, one of said electrodes being connected to a point on the plate circuit and the other of said electrodes being connected to a point on the grid circuit, and so disposed as to maintain oscillations with the frequency of a mode of vibration of the electro-mechanical vibrator, said frequency being substantially independent of electrical tuning of any of said electric circuits.

2. An electro-mechanical system having, in combination, a vacuum tube, a grid circuit and a plate circuit through said tube, an electro-mechanical vibrator having two electrodes serving conjointly both for stimulation and response, one of said electrodes being connected to a point on the plate circuit and the other of said electrodes being connected to the grid, and so disposed as to maintain oscillations with the frequency of a mode of vibration of the electro-mechanical vibrator, said frequency being substantially independent of elecrical tuning of any of said electric circuits.

3. An electro-mechanical system having, in combination, vacuum-tube apparatus comprising a cathode electrode, a grid electrode and an anode electrode, an electro-mechanical vibrator having two electrodes only, means connecting one of the vibrator electrodes to the anode electrode, means connecting the other vibrator electrode to the grid electrode, and connections whereby the system is adapted to oscillate with the frequency of a mode of vibration of the electro-mechanical vibrator and widely independent of the electrical constants of the system.

4. An electro-mechanical system having, in combination, a vacuum tube having a cathode electrode, a grid electrode and an anode elec-

trode, an electro-mechanical vibrator having electrodes disposed substantially perpendicular to an electric axis of the vibrator, means connecting one of the vibrator electrodes to the grid electrode, means connecting the other vibrator electrode to the anode electrode plate, and connections whereby the system is adapted to oscillate with the frequency of a mode of vibration of the electro-mechanical vibrator in substantially the direction of the said electric axis and widely independent of the electrical constants of the system.

5. An electro-mechanical system having, in combination, a vacuum tube comprising a cathode electrode, a grid electrode and an anode electrode, a condenser and an inductance connected with the cathode electrode and the anode electrode in parallel relation, and an electro-mechanical vibrator connected with the anode electrode and the grid electrode.

6. In a piezo-electric-crystal oscillating circuit, a crystal, a pair of metal contact plates on each side thereof, said plates being connected respectively to the grid and filament terminals of a vacuum tube, an impedance element, one end of which is connected to one terminal of a source of potential and so arranged that the opposite terminal of the impedance element is connected to the grid of the vacuum tube while the other terminal of said source of potential is connected direct to the filament of said tube, and a plate oscillating system which comprises the plate of the vacuum tube, a choke coil, a radio frequency by-pass condenser, a high potential source and a resonant circuit consisting of an inductance, a capacity and a resistance.

7. In a piezo-electric-crystal oscillating circuit, a vacuum tube comprising a cathode electrode, a grid electrode and an anode electrode, input and output circuits connecting the electrodes, a crystal, a pair of metal contact plates on each side thereof, said plates being connected respectively to the grid electrode and the cathode electrode, and an impedance element one end of which is connected to one terminal of a source of potential and so arranged that the opposite terminal of the impedance element is connected to the grid electrode while the other terminal of said source of potential is connected to the cathode electrode, the output circuit having an oscillating system comprising the anode electrode, an inductance, a high-potential source, and a resonant circuit.

8. In a piezo-electric-crystal oscillating circuit, a vacuum tube having grid, cathode and anode electrodes, a crystal, a pair of metal contact plates on each side thereof, said plates being connected respectively to the grid electrode and one of the other two said electrodes of the vacuum tube, and an impedance element one end of which is connected to one terminal of a source of potential and so arranged that the opposite terminal of the impedance element is connected to the grid electrode while the other terminal of said source of potential is connected to the cathode electrode, the output circuit having an oscillating system comprising the anode electrode, an inductance, high-potential source, and a resonant circuit.

9. An electromechanical system having, in combination, a tube comprising a cathode electrode, a grid electrode and an anode electrode, an output circuit connected with two of the electrodes, an electrognechanical vibrator connected with the cathode electrode and the grid electrode, a transformer having a winding connected in parallel with the vibrator and a second winding, whereby the system is adapted to oscillate with the frequency of a mode of vibration of the vibrator, and a microphone in circuit with the second winding.

10. An electromechanical system having, in combination, a tube comprising a cathode electrode, a grid electrode and an anode electrode, an output circuit connected with two of the electrodes, a grid-biasing source of energy for the grid electrode, an electromechanical vibrator connected with two of the electrodes, a winding in circuit with the grid electrode in parallel relation to the vibrator, and a modulating means in inductive relation to said winding.

11. An electric system having, in combination, a tube having an input circuit and an output circuit, the circuits being substantially uncoupled together except through the tube, and an electromechanical vibrator connected in the input circuit to cause the system to oscillate at a frequency of a mode of vibration of the vibrator.

12. An electric system having, in combination, a hermetically sealed container within which are contained a cathode electrode and a plurality of additional electrodes, an input circuit including the cathode electrode and one of the additional electrodes, an output circuit coupled to the input circuit and including the cathode electrode and another of the additional electrodes, and an electromechanical vibrator connected in the input circuit only, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator and such as to render the system stably non-oscillatory when not under the control of the vibrator, and the input circuit being substantially untuned except through the vibrator.

13. An electric system having, in combination, vacuum-tube apparatus having an input circuit and an output circuit coupled to the input circuit, and a piezo-electric body and an inductance connected in parallel in the input circuit, the input circuit being substantially untuned except through the body.

14. An electric system having, in combination, vacuum-tube apparatus having an input circuit and an output circuit coupled to the input circuit, a piezo-electric body and an inductance connected in parallel in the input circuit, the input circuit being substantially untuned except through the body, and a battery in series with the inductance.

15. An electric system having, in combination, vacuum-tube apparatus having an input circuit and an output circuit coupled together and each having an inductance, the inductances not being coupled together, and a piezo-electric body connected in parallel to the input-circuit inductance.

16. An oscillatory system having, in combination, a vacuum tube, a source of energy, a piezo-electric crystal body having two electrodes only, and means connecting the tube, the source and the body together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the body at a substantially constant frequency determined by a mode of vibration of the body, and such as to render the system stably non-oscillatory when not under the control of the body.

17. An oscillatory system having, in combina-

tion, vacuum-tube apparatus comprising a cathode electrode, a grid electrode and an anode electrode, a source of energy, a piezo-electric crystal body having two electrodes only connected with the tube electrodes, means for biasing the grid electrode, and means connecting the vacuum-tube apparatus, the source and the body together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the body at a substantially constant frequency determined by a mode of vibration of the body, and such as to render the system stably non-oscillatory when not under the control of the body.

18. An oscillatory system having, in combination, a single vacuum tube having a cathode electrode, a grid electrode and an anode electrode, a source of energy, a single piezo-electric crystal body, an impedance, a grid-biasing source of energy for the grid electrode, and means connecting the source between the cathode electrode and the anode electrode, and the body, the impedance and the grid-biasing source between the cathode electrode and the grid electrode to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the body at a substantially constant frequency determined by a mode of vibration of the body, and such as to render the system stably non-oscillatory when not under the control of the body.

19. An oscillatory system having, in combination, a vacuum tube, a source of energy, an electromechanical vibrator, and means connecting the tube, the source and the vibrator together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator in substantially the direction of a shorter dimension of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator.

20. An oscillatory system having, in combination, vacuum-tube apparatus having a plurality of electrodes, a source of energy, a piezo-electric body having a pair of electric terminals, said terminals being disposed transversely to an electric axis of the body and being connected with the electrodes, and means connecting the vacuum-tube apparatus, the source and the body together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the body at a substantially constant frequency determined by a mode of vibration of the body corresponding to the direction of the said electric axis, and such as to render the system stably non-oscillatory when not under the control of the body, stimulation existing between said terminals and response existing between the same said terminals during the oscillation of the system, whereby the system will be maintained in oscillation and the body in vibration at the said frequency and widely independent of the electrical parameters of the system.

21. An oscillatory system having, in combination, a hermetically sealed container having a cathode electrode, a control electrode and an anode electrode, a circuit coupled to the control electrode and the cathode electrode, another circuit coupled to the cathode electrode and the anode electrode, means for subjecting the anode electrode and the control electrode in the respective said circuits to suitable operating potentials, an electromechanical vibrator having two electrodes only, and means coupling the vibrator to two of the electrodes to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the system stably non-oscillatory when not under the control of the crystal.

22. An oscillatory system having, in combination, vacuum-tube apparatus having a cathode electrode, a grid electrode and an anode electrode, a circuit including said anode electrode and said cathode electrode, another circuit including said grid electrode and said cathode electrode, a piezo-electric crystal having a pair of electrodes disposed transversely to an electric axis of the crystal, and means connecting the crystal electrodes in one of the said circuits to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal corresponding to the direction of the said electric axis, and such as to render the system stably non-oscillatory when not under the control of the crystal.

23. An oscillatory system having, in combination, a vacuum tube comprising a cathode electrode, a grid electrode and an anode electrode, an input circuit connected with the cathode electrode and the grid electrode, an output circuit connected with the cathode electrode and the anode electrode, an electromechanical vibrator having a pair of terminals connected with two of the electrodes, and a source of energy connected in the output circuit, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator and widely independent of the electrical parameters of the system, and such as to render the system stably non-oscillatory when not under the control of the vibrator, stimulation existing between said terminals and response existing between the same said terminals during the oscillation of the system.

24. An oscillatory system having, in combination, a vacuum tube comprising a cathode electrode, a grid electrode and an anode electrode, a source of energy, an electromechanical vibrator having a pair of terminals connected with the electrodes, and means connecting the source between the cathode electrode and the anode electrode and the vibrator between the cathode electrode and the grid electrode to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator, stimulation existing between said terminals and response existing between the same said terminals during the oscillation of the system.

25. An oscillatory system having, in combina-

tion, a vacuum tube comprising a cathode electrode, a grid electrode and an anode electrode, a source of energy, an electromechanical vibrator having a pair of terminals connected with the electrodes, an impedance, and means connecting the source between the cathode electrode and the anode electrode and the vibrator and the impedance in parallel relation between the cathode electrode and the grid electrode to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator, stimulation existing between said terminals and response existing between the same said terminals during the oscillation of the system.

26. An oscillatory system having, in combination, a vacuum tube comprising a cathode electrode, a grid electrode and an anode electrode, a source of energy, an electromechanical vibrator having electric terminals connected with the electrodes, a resistor, and means connecting the source between the cathode electrode and the anode electrode and the vibrator and the resistor in parallel relation between the cathode electrode and the grid electrode to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator, stimulation existing between said terminals and response existing between the same said terminals during the oscillation of the system.

27. An oscillatory system having, in combination, vacuum-tube apparatus having an input circuit and an output circuit, a source of energy, a piezo-electric body, the input and output circuits being mechanically uncoupled, and means connecting the input and output circuits, the source and the body together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the body at a substantially constant frequency determined by a mode of vibration of the body, and such as to render the system stably non-oscillatory when not under the control of the body.

28. An oscillatory system having, in combination, an amplifying relay having a plurality of electrodes, a source of energy, an electromechanical vibrator having two electrodes only, means connecting the relay, the source and the vibrator together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator, a winding connected with two of the relay electrodes, and means connected with the winding for transmitting electric wave energy to the system.

29. An electric system having, in combination, vacuum-tube apparatus having an input circuit and an output circuit, an electromechanical vibrator having two electrodes only and connected in the input circuit only, a source of energy connected in the output circuit, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator, and means for modulating the oscillations in the system.

30. An electric system having, in combination, vacuum-tube apparatus having an input circuit and an output circuit and each having a coil, an electromechanical vibrator, and means connecting the vacuum-tube apparatus, the circuits and the vibrator together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and the coils having inter-relations of such character and amount as to render the system incapable of fortuitously becoming oscillatory in the absence of the vibrations of the vibrator.

31. An electromechanical system having, in combination, an hermetically sealed container having therein an electron-emitting cathode, an inner cold electrode and an outer cold electrode, input and output circuits interconnecting the electrodes, an electromechanical vibrator, a source of energy, and means connecting the vacuum-tube apparatus, the source and the vibrator together to constitute a regenerative oscillatory system, substantially all the regeneration being effected through capacitive coupling between said cold electrodes within said hermetically sealed container, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and the circuit connections and couplings being of such character as to inhibit parasitic oscillations of the system.

32. An oscillatory system having, in combination, a hermetically sealed container having therein a cathode electrode and a plurality of cold electrodes, circuits connecting said cold electrodes with said cathode electrode, a piezo-electric crystal having two electrodes only, and means connecting the crystal in the system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the system stably non-oscillatory when not under the control of the crystal.

33. An electromechanical system having, in combination, vacuum-tube apparatus, input and output circuits connected with the apparatus, and a piezo-electric body connected with the system, the circuits being substantially uncoupled together except through the vacuum-tube apparatus, whereby the system will oscillate at a frequency of a mode of vibration of the body.

34. An electromechanical system having, in combination, an amplifying relay having an input circuit and an output circuit, a piezo-electric body, the circuits being substantially uncoupled together except through the relay, a source of energy, and means connecting the relay, the source and the body together to constitute an oscillatory system, whereby the frequency

of the oscillations of the system will be substantially constant and determined by a mode of vibration of the body.

35. An electric system having, in combination, an amplifying relay having an input circuit and an output circuit, the circuits being coupled through the relay, and a piezo-electric body and an inductance connected in parallel in the input circuit, the input circuit being substantially untuned except through the body.

36. An electric system having, in combination, an amplifying relay having an input circuit and an output circuit, the circuits being coupled through the relay, a source of energy in the output circuit, a piezo-electric body and an inductance connected in parallel in the input circuit, the input circuit being substantially untuned except through the body, and a battery in series with the inductance.

37. An electric system having, in combination, an amplifying relay having an input circuit and an output circuit, the circuits being coupled through the relay, a source of energy in the output circuit, and a piezo-electric body and an inductance connected in parallel in the input circuit, the input circuit being substantially untuned except through the body.

38. An oscillatory system having, in combination, an electromechanical vibrator with two electric terminals, said terminals serving both for electric stimulation and electric response, a source of electric energy, an amplifying device and connections to maintain the system in vibration with a frequency widely independent of the electrical constants of the system, the electrical parameters of the system being such that the system is inhibited from fortuitously becoming oscillatory in the absence of the vibrator.

39. An oscillatory system having, in combination, an electromechanical vibrator with two electric terminals, said terminals serving both for electric stimulation and electric response, a source of electric energy, a repeating device and connections to maintain the system in vibration with a frequency widely independent of the electrical constants of the system, the electrical parameters of the system being such that the system is inhibited from fortuitously becoming oscillatory in the absence of the vibrator.

40. An oscillatory system having, in combination, an electromechanical vibrator comprising a piezo-electric body with two electric terminals, said terminals serving both for electric stimulation and electric response, a source of electric energy, an amplifying device and connections to maintain the system in vibration with a frequency widely independent of the electrical constants of the system, the electrical parameters of the system being such that the system is inhibited from fortuitously becoming oscillatory in the absence of the vibrator.

41. An oscillatory system having, in combination, an electromechanical vibrator with two electric terminals, said terminals serving both for electric stimulation and electric response, a source of electric energy, a vacuum-tube amplifying device and connections to maintain the system in vibration with a frequency widely independent of the electrical constants of the system, the electrical parameters of the system being such that the system is inhibited from fortuitously becoming oscillatory in the absence of the vibrator.

42. An electromechanical system having, in combination, a vacuum tube having a cathode electrode, a grid electrode and an anode electrode, an electromechanical vibrator having two electrodes, one of the vibrator electrodes being connected with one of the vacuum-tube electrodes and the other vibrator electrode being connected with another of the vacuum-tube electrodes, whereby the two vibrator electrodes are adapted to act conjointly both for stimulation and response, and connections whereby the system is adapted to oscillate with the frequency of a mode of vibration of the electromechanical vibrator, the electrical parameters of the system being such that the system is inhibited from fortuitously becoming oscillatory in the absence of the vibrator.

43. An electromechanical system having, in combination, vacuum-tube apparatus comprising a plurality of electrodes, an electro-mechanical vibrator having two electrodes, means connecting one of the vibrator electrodes to one of the plurality of electrodes, means connecting the other vibrator electrode to another of the plurality of electrodes, whereby the two vibrator electrodes are adapted to act conjointly both for stimulation and response, and connections whereby the system is adapted to oscillate with the frequency of a mode of vibration of the electromechanical vibrator and widely independent of the electrical constants of the system, the electrical parameters of the system being such that the system is inhibited from fortuitously becoming oscillatory in the absence of the vibrator.

44. An electromechanical system having, in combination, a vacuum tube having three electrodes, an electromechanical vibrator having electrodes disposed substantially perpendicular to an electric axis of the vibrator, means connecting one of the vibrator electrodes to one of the tube electrodes, means connecting the other vibrator electrode to another of the tube electrodes, and connections whereby the system is adapted to oscillate with the frequency of a mode of vibration of the electromechanical vibrator in substantially the direction of the said electric axis and widely independent of the electrical constants of the system.

45. An electromechanical system having, in combination, vacuum-tube apparatus comprising a plurality of electrodes, an electromechanical vibrator having electrodes disposed substantially perpendicular to an electric axis of the vibrator, means connecting one of the vibrator electrodes to one of the plurality of electrodes, means connecting the other vibrator electrode to another of the plurality of electrodes, and connections whereby the system is adapted to oscillate with the frequency of a mode of vibration of the electromechanical vibrator in substantially the direction of the said electric axis and widely independent of the electrical constants of the system.

46. An electromechatical system having, in combination, vacuum-tube apparatus comprising a plurality of electrodes, an electromechanical vibrator connected with two of the electrodes, whereby the system is adapted to oscillate with the frequency of a mode of vibration of the electromechanical vibrator, a transformer having a winding connected with two of the electrodes and a second winding, and a microphone in circuit with the second winding.

47. An electromechanical system having, in combination, vacuum-tube apparatus comprising a plurality of electrodes, a biasing source of energy for one of the electrodes, an electromechanical vibrator connected with two of the electrodes, a winding in circuit with the said one electrode and another electrode, and a micro-

phone and a winding coupled to the first-named winding in circuit with the microphone.

48. An oscillatory system having, in combination, an electric circuit, a piezo-electric crystal having two electrodes only and in which response coexists with stimulation during the oscillations of the system, the electrodes being connected with the circuit to cause the system to oscillate at the frequency determined by a mode of vibration of the crystal, the parameters of the system having electrical characteristics such that the system is inhibited from fortuitously becoming oscillatory in the absence of the vibrations of the vibrator.

49. An electromechanical system having, in combination, a vacuum tube having a grid electrode, an anode electrode and a cathode electrode, means for biasing said grid electrode, a grid circuit and an anode circuit coupled through said tube, and a piezo-electric crystal having two electrodes serving conjointly both for stimulation and response, said electrodes being connected respectively to the grid electrode and the cathode electrode, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal and substantially independent of electrical tuning of any of said electric circuits, and the said parameters having values stably far removed from values that would render the system oscillatory in the absence of the crystal.

50. An oscillatory system having, in combination, vacuum-tube apparatus having a cathode electrode, a grid electrode and an anode electrode, a circuit including said anode electrode and said cathode electrode, another circuit including said grid electrode and said cathode electrode, a piezo-electric crystal, and means connecting the crystal in one only of the said circuits to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the system stably non-oscillatory when not under the control of the crystal.

51. In an oscillation generator, a vacuum tube, a quartz crystal in circuit with said tube, and a tunable resonant circuit connected in the output circuit of the tube.

52. In an oscillation generator, a three electrode vacuum tube, a piezo-electric element in circuit with the grid electrode and one other electrode of said tube, and a parallel connected inductance and capacity constituting a tunable resonant circuit in the output circuit of said tube.

53. In an oscillation generator, a three electrode vacuum tube, a piezo-electric element in circuit with two electrodes of the tube, means associated with the tube for obtaining oscillations in said element, and a leakage path from the grid electrode to the filament electrode of said tube, said leakage path including a choke coil.

54. In an oscillation generator, a three electrode vacuum tube, a piezo-electric element having a natural period of oscillation in circuit with the grid and filament electrodes of said tube, and resonant means, in the plate circuit of the tube, said resonant means being tuned to a frequency of higher period than that of the element for obtaining oscillations at the natural period of the element.

55. In an oscillation generator, a vacuum tube, having an input circuit including a quartz crystal provided with two electrodes, a connection between one of said crystal electrodes and the grid electrode of said vacuum tube, another connection between the other of said crystal electrodes and another electrode of said vacuum tube and a tunable circuit external to said input circuit associated with the output circuit of said vacuum tube for obtaining electrical oscillations of a frequency determined by a natural frequency of vibration of said quartz crystal.

56. In an oscillation generator, a vacuum tube, having an input circuit including a quartz crystal provided with two electrodes, a connection between one of said crystal electrodes and the grid of said vacuum tube, another connection between the other of said crystal electrodes and the cathode of said vacuum tube and a tunable circuit external to said input circuit associated with the output circuit of said vacuum tube for obtaining electrical oscillations of a frequency determined by a natural frequency of vibration of said crystal.

57. In an oscillation generator, a single vacuum tube having an input circuit and an output circuit, a single piezo-electric element in circuit with the grid electrode and one other electrode only of said tube, an inductance connected in circuit with the plate electrode of said tube, and an impedance external to the input circuit adjustably connected to the inductance, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the system stably non-oscillatory when not under the control of the crystal.

58. In an oscillation generator, a vacuum tube having an input circuit and an output circuit, a quartz crystal provided with two electrodes only, connections between said electrodes and the grid and cathode of said vacuum tube, an inductance connected in the output circuit of said tube, and an inductance external to the input circuit adjustably coupled to the first-named inductance, a capacity being connected with one of the inductances, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the system stably non-oscillatory when not under the control of the crystal.

59. In an oscillation generator, a vacuum tube, a piezo-electric element in circuit with the grid and cathode of said vacuum tube, a leakage path including a choke coil connected between said grid and cathode and a tunable circuit associated with the output circuit of said vacuum tube.

60. In an oscillation generator, a vacuum tube, a piezo-electric element connected between the grid and another electrode of said vacuum tube, a leakage path including a choke coil connected between said grid electrode and cathode and a tunable circuit associated with the output of said vacuum tube.

61. In an oscillation generator, a vacuum tube, having a control circuit comprising a quartz crystal connected between a control electrode and another electrode of said vacuum tube and a resonant tunable circuit external to the control circuit of said tube and associated with a circuit between the cathode and an electrode of said vacuum tube which electrode is maintained at

an average potential different from that of said cathode.

62. In an oscillation generator, a vacuum tube, having an input circuit comprising a quartz crystal connected between a control electrode and cathode of said vacuum tube and a tunable resonant circuit external to said input circuit of said tube and associated with a circuit between the cathode and an electrode of said tube which electrode is maintained at an average potential different from that of said cathode.

63. In a system comprising a quartz crystal having a natural frequency of mechanical vibration and a vacuum tube, the method of generating electrical oscillations of constant frequency which consists in impressing voltages generated by vibrations of said quartz crystal between the grid and cathode of the vacuum tube, and adjusting the output circuit of said vacuum tube so that it has an inductive reactance for said natural frequency.

64. In a system comprising a quartz crystal having a natural frequency of mechanical vibration and a vacuum tube, the method of generating electrical oscillations of constant frequency which consists in impressing voltages generated by vibrations of said quartz crystal between the grid and another electrode of said vacuum tube, tuning the output circuit of said vacuum tube to a frequency approximately that of said natural frequency, and impressing the voltage across said output circuit through a capacity path upon said quartz crystal to sustain the vibrations thereof.

65. An oscillation generator comprising a three electrode vacuum tube, a piezo-electric element connected between the cathode and the grid of said tube for predetermining the frequency of the potential variations of the grid, and a circuit connected between the plate and the filament of said vacuum tube which is tuned to a frequency higher than the said predetermined frequency.

66. An oscillation generator comprising a vacuum tube, having at least a cathode, a plate and a grid, a piezo-electric element capable of vibrating at a plurality of frequencies connected between the cathode and the grid of said tube for predetermining the frequency of the potential variations of the grid, and a circuit interconnecting the plate and the cathode and tuned to a frequency higher than one of said plurality of frequencies.

67. A generating system of constant frequency oscillations comprising a vacuum tube, a piezo-electric element of hard, durable material provided with a single pair of operative electrodes in circuit with said tube, and a resonant circuit in the output of said tube carrying oscillating currents having a frequency determined at all times by a natural period of mechanical vibration of said piezo-electric element, said piezo-electric element constituting an essential element in the system for the generation of oscillations.

68. A generating system of constant frequency oscillations comprising an amplifier, a piezo-electric element of hard, durable material in circuit with said amplifier, and a resonant circuit in the output of said amplifier carrying oscillating currents having a frequency determined at all times by a natural period of mechanical vibration of said piezo-electric element, said piezo-electric element constituting an essential element in the system for the generation of oscillations.

69. An electromechanical system having, in combination, a plurality of tubes connected in cascade and each having a cathode electrode, a grid electrode and an anode electrode, and an electromechanical vibrator connected with the grid electrode and the anode electrode of one of the tubes.

70. An electromechanical system having, in combination, a plurality of tubes connected in cascade and each having a cathode electrode, a grid electrode and an anode electrode, and an electromechanical vibrator having two electrodes, one of the vibrator electrodes being connected to the grid electrode of one tube, and the other vibrator electrode being connected with the anode electrode of the said one tube.

71. The combination of a vacuum tube of the three-electrode type having an input circuit and an output circuit, a piezo-electric device opposite sides of which are connected between the plate and grid electrodes of the tube, said piezo-electric device coupling said circuits so that energy may be fed from the output circuit to the input circuit controlled and stabilized as to frequency in accordance with the natural period of the piezo-electric device, and means for controlling the amplitude of the current so fed back.

72. An oscillatory system having, in combination, lower and upper crystal electrodes having oppositely disposed substantially horizontal substantially flat surfaces, a piezo-electric crystal supported between the electrodes having oppositely disposed substantially flat faces disposed respectively adjacent and substantially parallel to the flat surfaces of the electrodes, the crystal having an electric axis substantially perpendicular to the said substantially flat faces of the crystal, a tube having three tube electrodes, namely, a cathode electrode, a grid electrode and an anode electrode, a circuit including two of the tube electrodes, and means connecting one of the crystal electrodes with one of the said two tube electrodes and the other crystal electrode with the third tube electrode to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the system stably non-oscillatory when not under the control of the crystal.

73. An oscillatory system having, in combination, lower and upper crystal electrodes having oppositely disposed substantially horizontal substantially flat surfaces, a piezo-electric crystal supported between the electrodes having oppositely disposed substantially flat faces disposed respectively adjacent and substantially parallel to the flat surfaces of the electrodes, the crystal having an electric axis substantially perpendicular to the said substantially flat faces of the crystal, a tube having a cathode electrode, a grid electrode and an anode electrode, a circuit including the grid electrode and the cathode electrode and comprising means for subjecting the grid electrode to a potential negative with respect to the potential of the cathode electrode, another circuit including the anode electrode and the cathode electrode and comprising a coil and means for applying a potential to the anode electrode positive with respect to the potential of the cathode electrode, and means connecting the crystal electrodes to the grid electrode and the cathode electrode to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system

oscillatory under the control of the crystal at a substantially constant frequency determined by that mode of vibration of the crystal corresponding to the direction of the said electric axis, and such as to render the system stably non-oscillatory when not under the control of the crystal.

74. An oscillatory system having, in combination, an amplifying relay having a plurality of electrodes, a source of energy, an electromechanical vibrator having two electrodes only, means connecting the relay, the source and the vibrator together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator, a winding connected with two of the relay electrodes, and means connected with the winding for transmitting electric wave energy from the system.

75. In an electrical system, an hermetically sealed container wherein are contained an electron-emitting cathode and a pair of cold electrodes spaced from said cathode, circuits interconnecting said pair of electrodes and said cathode, and a coupling circuit coupling together said cold-electrode-cathode circuits, said coupling circuit comprising a two-electrode piezo-electric crystal.

76. An oscillator comprising an electron discharge device having within an hermetically sealed container an electron-emitting cathode and a pair of relatively cold electrodes, circuits connecting said cold electrodes to said cathode for subjecting said cold electrodes to different polarizing potentials, and an electromechanical vibrator connected between said cold electrodes.

77. Apparatus as claimed in the preceding claim characterized further by the fact that said cold electrodes are unequally spaced from said cathode, that the cold electrode nearest said cathode is subjected to a negative potential with respect to said cathode, that the cold electrode further from said cathode is subjected to a relatively positive potential with respect to said cathode, and that the electromechanical vibrator is in the form of a piezo-electric crystal.

78. An oscillation generating system comprising an hermetically sealed container wherein are contained an electron-emitting cathode and a plurality of cold electrodes unequally spaced from and subject to different polarizing potentials with respect to said cathode, a piezo-electric crystal having two electrodes, and connections operatively connecting said crystal electrodes to said cold electrodes, whereby oscillations are produced at a frequency determined by said piezo-electric crystal.

79. Apparatus as claimed in the preceding claim characterized by the additional fact that an inductance coil is connected between one of said cold electrodes and said cathode.

80. Apparatus as claimed in claim 78 characterized by the fact that an inductance coil is connected between said electrode maintained at said relatively positive potential and said cathode.

81. In a frequency-control system, an electron tube having grid, filament and plate electrodes, input and output circuits interconnecting said electrodes, a high-potential supply system connected in said output circuit, an impedance element in series therewith, a piezo-electric-crystal element connected in said input circuit to control the operation of said circuits, and an independent impedance element connected in said input circuit, the output circuit comprising a high-frequency oscillation circuit connected to sustain therein high-frequency oscillations corresponding to the natural frequency of said piezo-electric-crystal element.

82. An oscillatory system having, in combination, an hermetically sealed container having therein an electron-emitting cathode electrode, an inner cold electrode and an outer cold electrode, a source of energy, an impedance, a piezo-electric crystal having two electrodes only, and means connecting the impedance and the source between said outer cold electrode and said cathode electrode and the crystal between said inner cold electrode and said cathode electrode to constitute a regenerative oscillatory system, substantially all of the regeneration being effected through capacitive coupling between said cold electrodes within said hermetically sealed container, with said crystal forming the only path between said inner cold electrode and said cathode in which high-frequency currents corresponding to a natural frequency of said crystal cause resonance effects, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal and such as to render the system stably non-oscillatory when not under the control of the crystal.

83. An oscillatory system having, in combination, an hermetically sealed container having therein an electron-emitting cathode electrode, an inner cold electrode and an outer cold electrode, a source of energy, an impedance, a piezo-electric crystal having two electrodes only, and means connecting the impedance and the source between said outer cold electrode and said cathode electrode and the crystal between said inner cold electrode and said cathode electrode to constitute an oscillatory system with said crystal forming the only path between said inner cold electrode and said cathode in which high-frequency currents corresponding to a natural frequency of said crystal cause resonance effects, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal and such as to render the system stably non-oscillatory when not under the control of the crystal.

84. An electron-tube oscillator comprising an electron tube having grid, cathode and plate electrodes, an output circuit connected across said plate and cathode electrodes, means controlling the frequency of said oscillator comprising a piezo-electric crystal, said piezo-electric crystal being in circuit with said grid and cathode electrodes, means connected in shunt with said piezo-electric crystal for preventing the crystal oscillating voltage from passing substantially beyond the zero grid-voltage point and becoming a positive voltage, and a resonant circuit connected with said output circuit for sustaining oscillations delivered by said piezo-electric crystal at a frequency corresponding to the natural frequency of said piezo-electric crystal.

85. An oscillatory system having, in combination, vacuum-tube apparatus, input and output circuits connected with the vacuum-tube apparatus, a piezo-electric body, a source of energy,

and means connecting the source in the output circuit and the body in the input circuit to constitute an oscillatory system the frequency of the oscillations of which shall be substantially constant and determined by a mode of vibration of the body, and means in the input circuit in parallel with the body for choking back currents of the frequency of the said oscillations.

86. An oscillatory system having, in combination, an hermetically sealed container having therein an electron-emitting cathode electrode, an inner cold electrode and an outer cold electrode, a source of energy, a coil, a piezo-electric crystal having only two electrodes connected respectively with said inner cold electrode and said cathode electrode, said crystal forming the only path between said inner cold electrode and said cathode electrode in which high-frequency currents corresponding to a natural frequency of said crystal cause resonance effects, a circuit connected between said cathode electrode and said inner cold electrode for subjecting said inner cold electrode to a negative potential with respect to said cathode electrode, a circuit connected between said outer cold electrode and said cathode electrode for subjecting said outer cold electrode to a positive potential with respect to said cathode, and means connecting the source of energy and the coil in the last-named circuit, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the system stably non-oscillatory in the absence of the crystal.

87. An oscillatory system having, in combination, an hermetically sealed container having therein an electron-emitting cathode electrode, an inner cold electrode and an outer cold electrode, a source of energy, a circuit having inductance and capacity, a piezo-electric crystal having only two electrodes, and means connecting said circuit and said source between said outer cold electrode and said cathode electrode and the crystal between said inner cold electrode and said cathode electrode to constitute an oscillatory system with said crystal forming the only path between said inner cold electrode and said cathode electrode which is subject to resonance effects by high-frequency currents of a frequency of the order of magnitude of the natural frequency of said crystal, and means for subjecting said inner cold electrode to a negative potential with respect to said cathode electrode, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the system stably non-oscillatory when not under the control of the crystal.

88. An electric system having, in combination, vacuum-tube apparatus having an input circuit and an output circuit, and an electromechanical vibrator connected in the input circuit only, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator, and the input circuit being substantially untuned for the frequency of oscillation except through the vibrator.

89. An electric system having, in combination, vacuum-tube apparatus having an input circuit and an output circuit, and an electromechanical vibrator and a path for direct current connected in parallel in the input circuit, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator and such as to render the system stably non-oscillatory when not under the control of the vibrator.

90. An electromechanical system having, in combination, vacuum-tube apparatus comprising a cathode electrode, a grid electrode and an anode electrode, a condenser and an inductance connected with two of the electrodes in parallel relation, an electromechanical vibrator having only two electrodes serving both for stimulation and response, and means connecting the vibrator electrodes with one of said two vacuum-tube-apparatus electrodes and with the third vacuum-tube-apparatus electrode to cause said system to oscillate with a frequency determined by said electromechanical vibrator.

91. An electromechanical system for producing oscillations having, in combination, a vacuum tube, a grid electrode, an anode electrode, and a cathode electrode actively cooperating therein, an admittance between the cathode electrode and the grid electrode, a second admittance between the cathode electrode and the anode electrode, one of said admittances being an electromechanical vibrator, and the other of said admittances being a tunable electric element, said system being adjusted to oscillate with a frequency determined by said electromechanical vibrator and essentially independent of variations of the parameters of the electrical elements of the system.

92. An oscillatory system having, in combination, a vacuum tube having a cathode electrode, a grid electrode and an anode electrode, a circuit including two of the electrodes, an electromechanical vibrator, and means connecting the vibrator with one of the said two electrodes and with the third electrode to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator.

93. An oscillatory system having, in combination, a hermetically sealed container having therein a cathode electrode and a plurality of cold electrodes, circuits connecting said cold electrodes with said cathode electrode, said circuits being substantially electrically and mechanically disassociated except at the common connection to the cathode electrode and except by virtue of the association of the cathode electrode and the cold electrodes within said container, a piezo-electric crystal having two electrodes only, and means connecting the crystal electrodes in one of said circuits to constitute an oscillatory system in which the crystal electrodes shall act conjointly both for stimulation and response, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the system stably non-oscillatory when not under the control of the crystal.

94. An electron discharge device oscillator comprising an electron discharge device having an anode a cathode and a control electrode, means for polarizing the electrodes of said electron discharge device, a piezo-electric crystal resonator coupled to electrodes of said electron discharge device, and, a choke coil effectively in shunt with said piezo-electric crystal, the inductance of the coil together with the capacity of the electrodes of said crystal and the interelectrode capacity of said electron discharge device being such as to resonate at a frequency substantially less than the frequency at which said crystal is caused to operate.

95. An electron discharge device oscillator comprising an electron discharge device having an anode a cathode and a control electrode, means for polarizing the electrodes of said device, a piezo-electric crystal for controlling the frequency of oscillations generated by said device, said piezo-electric crystal being connected between a plurality of electrodes of said device, a choke coil for supplying unidirectional potential to one of the electrodes to which said piezo-electric crystal is connected, the inductance of the choke coil together with the capacity of the electron discharge device and the electrodes of said crystal being such as to resonate at a frequency from 50 percent to 80 percent of the frequency of oscillations generated by said electron discharge device oscillator.

96. In apparatus of the character described, an electron discharge device having within an hermetically sealed container, an electron emitting cathode, an anode, and a grid structure intermediate said anode and cathode, a piezo-electric crystal connected to two of the electrodes of said electron discharge device for starting and maintaining oscillation generation by said device at a frequency corresponding to a natural frequency of said crystal, and, a circuit effectively in shunt with said crystal for establishing a unidirectional current path to an electrode of said device to which said crystal is connected, said circuit in combination with the capacities associated with said piezo-electric crystal being of such a value in impedance as to resonate at a frequency substantially lower than the frequency of oscillation of said crystal.

97. In apparatus of the character described, an electron discharge device having within an hermetically sealed container, an electron emitting cathode, an anode, and a grid structure intermediate said anode and cathode, a piezo-electric crystal connected to two of the electrodes of said electron discharge device for starting and maintaining oscillation generation by said device at a frequency corresponding to a natural frequency of said crystal, and, a circuit effectively in shunt with said crystal for establishing a unidirectional current path to an electrode of said device to which said crystal is connected, said circuit in combination with the capacities associated with said piezo-electric crystal being of such a value in impedance as to resonate at a frequency from 50 to 80 percent of the frequency of oscillation of said piezo-electric crystal.

98. Oscillatory apparatus comprising an electron discharge device having within an evacuated container an anode, an electrode emitting cathode and an electrode intermediate said anode and cathode, means for polarizing said intermediate electrode to a negative potential relative to said cathode, means to polarize said anode to a positive potential with respect to said cathode, an electromechanical resonator, and connections connecting said electromechanical resonator to two of said electrodes for starting and maintaining generation of oscillations at a frequency corresponding to a frequency of said electromechanical resonator, the inductance of said connections together with the electrical characteristics of said resonator and the interelectrode capacity of said device being such as to resonate at a frequency substantially less than the frequency at which said resonator vibrates.

99. An electron-discharge-device oscillator comprising an electron-discharge device having an anode electrode, a cathode electrode and a control electrode, means for polarizing the electrodes of said device, a piezo-electric crystal for controlling the frequency of oscillations generated by said device, said piezo-electric crystal being connected between a plurality of electrodes of said device, and a choke coil for supplying unidirectional potential to one of the electrodes to which said piezo-electric crystal is connected, the parameters of the oscillator having electrical characteristics such as to render the oscillator oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the oscillator stably non-oscillatory when not under the control of the crystal.

100. An electron-discharge-device oscillator comprising an electron-discharge device having an anode electrode, a cathode electrode and a control electrode, means for polarizing the electrodes of said electron-discharge device, and a piezo-electric crystal resonator having two electrodes only coupled to electrodes of said electron-discharge device, the parameters of the oscillator having electrical characteristics such as to render the oscillator oscillatory under the control of the resonator at a substantially constant frequency determined by a mode of vibration of the resonator, and such as to render the oscillator stably non-oscillatory when not under the control of the resonator.

101. An electron-discharge-device oscillator having, within an hermetically-sealed container, an electron-emitting cathode electrode, an anode electrode, and a grid-electrode structure intermediate said anode and cathode electrodes, and a piezo-electric crystal having two electrodes only connected to two of the electrodes of said electron-discharge device for starting and maintaining oscillation generation by said device at a frequency corresponding to a natural frequency of said crystal, the parameters of the oscillator having electrical characteristics such as to render the oscillator oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the oscillator stably non-oscillatory when not under the control of the crystal.

102. Apparatus of the character described, having, in combination, an electron-discharge-device oscillator having a single hermetically-sealed container provided with an electron-emitting cathode electrode, an anode electrode and a grid-electrode structure intermediate said anode and cathode electrodes, a single piezo-electric crystal connected to two of the electrodes of said electron-discharge device for starting and maintaining oscillation generation by said device at a frequency corresponding to a natural frequency of said crystal, and a circuit effectively in shunt with said crystal for establishing a unidirec-

tional current path to an electrode of said device to which said crystal is connected, the parameters of the oscillator having electrical characteristics such as to render the oscillator oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, and such as to render the oscillator stably non-oscillatory when not under the control of the crystal.

103. Oscillatory apparatus comprising an electron-discharge device having within an evacuated container an anode electrode, an electron-emitting cathode electrode and an electrode intermediate said anode and cathode electrodes, means for polarizing the electrodes of said electron-discharge device, an electromechanical resonator having two electrodes only, and connections connecting said electromechanical resonator to two of said electrodes for starting and maintaining generation of oscillations at a frequency corresponding to a frequency of said electromechanical resonator, the parameters of the oscillatory apparatus having electrical characteristics such as to render the oscillatory apparatus oscillatory under the control of the resonator at a substantially constant frequency determined by a mode of vibration of the resonator, and such as to render the oscillatory apparatus stably non-oscillatory when not under the control of the resonator.

104. An oscillatory system having, in combination, a single vacuum tube, having a cathode electrode, a grid electrode and an anode electrode, a source of energy, a single piezo-electric crystal body, an impedance connected in parallel relation to the body, and means connecting the source between the cathode electrode and the anode electrode, and the body and the impedance between the cathode electrode and the grid electrode to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the body at a substantially constant frequency determined by a mode of vibration of the body, and such as to render the system stably non-oscillatory when not under the control of the body.

105. A method of controlling the frequency of vibration of a piezo-electric crystal that comprises changing the temperature of the crystal from normal room temperature to a temperature to cause oscillation at a desired substantially precise frequency of vibration.

106. In a piezo-electric-crystal apparatus comprising lower and upper crystal electrodes having oppositely disposed substantially horizontal substantially flat surfaces, and a piezo-electric crystal having substantially flat upper and lower substantially horizontal faces, the crystal resting on the lower electrode with its upper substantially flat face adjacent to the substantially flat lower face of the upper electrode, the crystal having an electric axis substantially perpendicular to the said substantially flat faces of the crystal, a method of controlling the frequency of operation that comprises changing the temperature of the crystal from normal room temperature to a temperature to cause oscillation at a desired substantially precise frequency of operation.

GEORGE W. PIERCE.

APPENDIX K

U. S. Patent No. 2,133,646, October 18, 1938

(See Pages 117 to 125 Opposite ☞)

117

Oct. 18, 1938. G. W. PIERCE 2,133,646

ELECTRICAL SYSTEM

Filed April 9, 1930

Fig. 1.

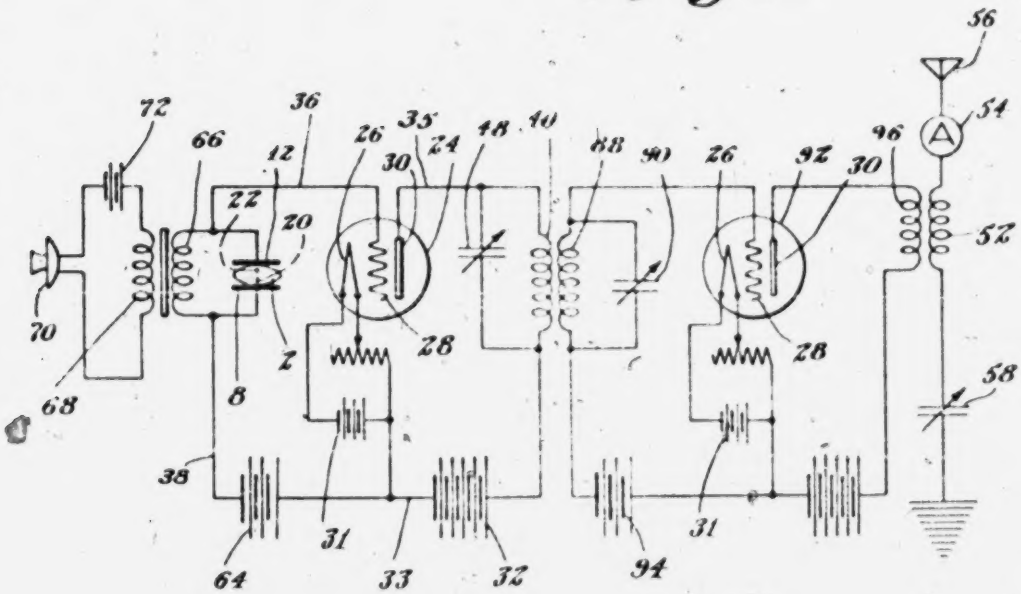
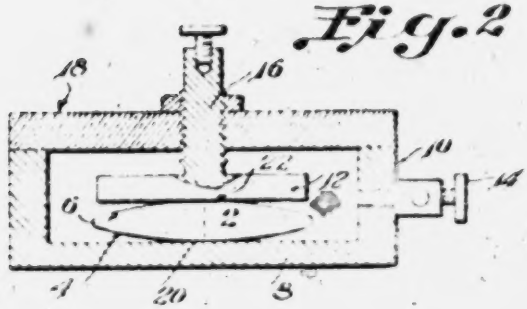


Fig. 2



Inventor
George W. Pierce
by Sand Rines
Attorney

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ELECTRICAL SYSTEM

George Washington Pierce, Cambridge, Mass.

Continuation of application Serial No. 659,094, February 25, 1934. This application April 9, 1930, Serial No. 442,862

29 Claims. (Cl. 250—17)

The present invention relates to electrical systems, and more particularly to oscillatory systems controlled by electromechanical vibrators. From a more limited aspect, the invention relates to the transmission of intelligence. The present application is a continuation of a copending application, Serial No. 695,094, filed February 25, 1924.

Electromechanical vibrators of the type described in the said application have the property of executing mechanical vibrations under vibratory electrical stimulus; and, conversely, of developing electrical potentials as a result of their mechanical vibrations. Piezo-electric bodies,—such as a whole crystal or part of a crystal of quartz, Rochelle salt, tourmaline, and the like,—have long been known to possess this property. Such bodies possess at least one, and usually two or more, axes—known as the electrical axes of the body—that have definite orientations in the original crystal. When a potential gradient, with a component in the direction of an electric axis, is applied to such a crystal body, the body undergoes mechanical deformations; and conversely, when the crystal body is deformed, a potential gradient is established in the body. The action of the electric forces to cause mechanical displacement will be called "stimulation"; and the development of electromotive force by the displacement will be called "response". The crystal body is, in general, capable of two or more particular modes of mechanical vibration, of different frequency, that correspond to two or more of its dimensions. These mechanical and electrical effects are normally transitory, for the crystal body will not, of itself, persist in continuous vibration. As described in the said application, however, the crystal may be so connected into circuit as to render these effects oscillatory in character and persistent, the said circuit then producing oscillations at very nearly constant frequency. A novel electrical system is thus produced comprising an electric circuit that is not, in itself, capable of sustaining oscillations, and that is not, in itself, a source of alternating currents, in combination with an electromechanical vibrator that will not, in itself, persist in continuous vibration; the connections being such, however, that the resulting electrical system will sustain oscillations of a frequency determined, to a high degree of precision, by the frequency of one of the modes of mechanical vibration of the electromechanical body.

An object of the present invention is to provide a novel system for producing high-frequency or short-wave oscillations derived from and harmonically related to crystal-controlled oscillations of very nearly constant frequency.

Another object is to vary the harmonically related frequency.

A further object is to provide a novel radio transmitter for transmitting at high frequency and embodying such novel system.

In radio telegraphy, it is customary to transmit signals by means of electric waves with a frequency that is desired to be constant. In radio telephony and radio telegraphy, and in carrier-current systems, where transmitting is effected by means of a carrier wave, also, the carrier frequency may be suppressed at the sending station, one side band alone being transmitted. In most cases it is important to maintain the oscillations of transmitters accurately constant; otherwise, the transmitting stations will interfere with each other. The more nearly constant their frequencies are, the more numerous may be the transmitting stations, without such interference.

Crystal-controlled oscillators are inherently very low-power devices, and this is particularly true in the case of high-frequency oscillators for which the controlling crystal must be very small and fragile. Transmitters, nevertheless, require high power. Another object of the present invention, therefore, is to provide an improved crystal-controlled system for transmitting electrical signals, particularly at a frequency harmonically related to the crystal frequency, to provide for an accurate control of the transmitting-station frequency, thereby to reduce interference to a minimum and to avoid the use of extremely small crystals.

Other and further objects of the invention will be explained hereinafter, and will be pointed out in the appended claims, it being understood that it is intended to cover in the appended claims all the novelty that the invention may possess.

In the accompanying drawing, Fig. 1 is a diagram of circuits and apparatus illustrating an operable embodiment of the invention; and Fig. 2 is a section of a modified form of mechanical-vibrator holder.

The radio transmitter of the present invention is illustrated as comprising a crystal-controlled master oscillator, a frequency multiplier coupled thereto, means for modulating the oscillations, and a radiating antenna or signal-transmission circuit.

As a setting to a description of the specific oscillator illustrated, reference will first be made to the electromechanical vibrator for determining the wave frequency. Though the vibrator is illustrated as of the piezo-electric type, the invention is not, in its broader aspects, limited to such a crystal body, but may employ any body or mechanism having like properties in itself, or like properties introduced by electric currents, electric polarization, magnetic fields, etc. At 2 is shown a piezo-electric body, which has one of its electrical axes approximately along the line 20—22, in the direction of the thickness of the crystal plate. This body may be of any desired form, as, for example, the lenticular shape illustrated and described in the above-mentioned application. It may be constituted of any suitable substance having sufficiently pronounced piezo-electric properties. Quartz is preferred, because of its durability and constancy. The term "electromechanical vibrator"—or, more simply, the term "vibrator"—will be employed hereinafter, in the specification and the claims, to denote any substance or arrangement, whether or not crystalline in character, that is endowed with the above-referred-to property of changing shape or dimensions under the action of an electric force or an electric current and of reacting on the electric circuits.

The oppositely disposed sides or surfaces 4 and 6 of the body 2 are provided with opposed conducting electrodes, terminals or plates 8 and 12, substantially perpendicular to an electric axis of the crystal, and arranged to act conjointly for stimulation and response. It is by means of these electrodes or terminals that the crystal is adapted to be connected into an electric circuit.

In Fig. 2, the electrode 8 is shown constituted of a flat bottom or base plate of a metal box, container or housing 10, within which the vibrator 2 is centrally located, as shown. The vertical side walls 11 of the housing 10 are integral with the base plate 8. The side or surface 4 is shown engaging the bottom or base plate 8. The opposite side or surface 6 contacts with, or is near to, the electrode 12 disposed in the housing 10 between the crystal and an insulating cover 18. The cover 18 may be constituted of hard rubber. The crystal is thus secured in the casing or housing 10 between the electrodes 8 and 12 without being in any way restricted, so that it is free to vibrate mechanically between the opposed electrodes 8 and 12 according to any of its modes or periods of natural vibration or any of its overtones of such modes of vibration. The electrode 8 is electrically connected to a binding post 14, and the plate 12 is electrically connected to a binding post 16. The binding post 14 is secured to a side wall 11, and the binding post 16 is suspended over the crystal 2. Electrical connection may be established between the two sides 4 and 6 of the crystal by means of conductors leading to the terminal binding posts 14 and 16 exterior of the housing. The binding post 16 may be in the form of a thumb screw, threaded through the cover 18, as shown, and secured to the electrode 12. The position of the electrode 12 may thus be shifted manually in parallel planes toward and away from the surface 6 of the crystal 2, to cause the electrodes 12 to approach the vibrator 2 more or less nearly, as desired, or into pressure contact with the vibrator 2, by screwing the binding post 16 in one direction or the other.

Being free to vibrate according to the desired mode of vibration, longitudinal or transverse, without restriction, and without interference with its vibrations, the crystal will vibrate without introducing variations in frequency, and the constancy of frequency is unaffected from error sources of this nature. I have found, however, that very minute variations of frequency of the order of one three-hundredth of one per cent may be introduced by bringing the electrodes more or less near to the piezo-electric vibrator. This is of importance in the final adjustment of such a vibrator, where extreme precision of frequency is required.

By means of this variable-capacity coupling between the crystal and the tuned circuit, the oscillator is thus capable of generating any wave within the limits of a predetermined band, and the period of the crystal may be increased or decreased by any desired amount so that the oscillator may sustain oscillations of any selected frequency within the predetermined band.

The illustrated oscillator comprises a multi-electrode vacuum or electron or electron-discharge tube 24, diagrammatically shown as provided with three sensitive elements or electrodes, namely, a cathode or filament 26, a plate or anode 30 and a grid 28 for controlling the transmission of current between the cathode and the anode. The master oscillator has an input circuit between or including the grid 28 and the cathode 26 and an anode or output circuit between or including the cathode 26 and the plate 30. The invention is not restricted to the use of this particular type of tube, but it will serve for illustrative purposes; it being understood, however, that the terms "plate" and "grid", as used herein, will include within their scope other sensitive elements of different types of tubes, and that the term "cathode" or "filament" will be employed, in the specification and the claims, to include any suitable means for rendering the space of the tube conducting,—exemplified in the drawing by the filament proper 25 connected to the filament-heating battery 31. A plate battery 32 is connected with the filament 25 by a conductor 33, and with the plate 30 by a conductor 35, and constitutes a source of energy for the plate 30. An element 40, shown in the form of an inductance coil, is connected between the battery 32 and the conductor 35.

The electrode 12 of the electro-mechanical vibrator is connected by a conductor 36 with the grid, and the other electrode 8 by a conductor 38 with the filament 26. A single crystal is thus shown, for illustrative purposes, as connected in the input circuit, between the filament 26 and the grid 30, but it may be connected between any two of the three tube electrodes, or have other locations, as explained in the said application. As is also explained in the said application, the mode of vibration depends somewhat on the points of connection of the vibrator in the circuit.

An impedance element 66, shown as the secondary winding of a modulation transformer, but which may be replaced by a resistor of high resistance with a new disposition of the hereinafter-described microphone 70, is connected in the grid circuit in parallel with the electrodes 8 and 12. The impedance element 66 may be constituted to give the grid a suitable potential about which its fluctuations occur. If desired, a biasing battery 64 may be employed to bias the grid 28 to a predetermined negative potential. The potential of the grid will then fluctuate

about the biased value. Assuming the parameters of the circuit to be properly chosen to produce crystal-controlled oscillations, as by approximate adjustment of the various elements of the system, the system will oscillate with a frequency determined by the frequency of some resonant mode of mechanical vibration of the electromechanical vibrator; that is, the parameters of the system will have electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency that is stabilized and determined by some mode of mechanical vibration of the vibrator, substantially independent of the value of the element 40, and such as to render the system stably non-oscillatory when not under the control of the vibrator.

This system, therefore, which can not oscillate in the desired frequency ranges, in its stable condition, with the crystal absent, is thus combined with the vibrator to produce a self-oscillating master oscillator, under the control of the vibrator. The vibrator is stimulated by the oscillations to maintain it in vibration and responds to maintain the system in oscillation with a fixed period determined by the vibrator. It is the vibrator itself, therefore, that provides automatically, by its presence, all the necessary additional electrical parameters or constants, such as inductances and capacitances, and the right transfer of energy from one part of the system to another, to render the relations among the reactances proper for producing oscillations.

Even wide variation of the electric parameters of the system have but an exceedingly slight effect upon the frequency of the oscillations, except in certain cases where certain controlled changes may result in shifting the frequency from that of one mode to that of another distinct mode. As explained in the said application, the disturbing effects—such as those produced by changes of temperature, changes of mounting supports, changes of electrical constants and the like,—on the frequency of the oscillations usually amount to less than one one-hundredth of one per cent of the frequency.

For some purposes, the power of the system may be increased by electrical tuning of some element of the system into or near resonance with the frequency of the mechanical vibrations of the vibrator. To understand what is meant by the term "tuning", it will be recalled that, when a circuit exhibits inductive reactance for one band of frequencies, capacitive reactance for a second band of frequencies, and zero reactance for a particular frequency between these two bands, the circuit is said to be "tuned" or "resonant" at the said particular frequency. Alternatively, this may be stated in terms of the phase relation between the voltage across the circuit and the current through the circuit. When, at any particular frequency, a circuit that exhibits reactance at other frequencies exhibits an impedance that is a pure resistance at the said particular frequency, so that the said current and the said voltage are in phase, that circuit is said to be tuned or resonant at the said particular frequency.

An easy way of selecting suitable circuit parameters for oscillation controlled by any vibrational mode of the crystal is to tune the circuit elements. For example, the plate or output circuit of the tube 24 may be adjusted by means of the condenser 48, so as to obtain high-current output. Due to the action of the crystal in maintaining constant the oscillation frequency, such adjustments are not critical; oscillations will be generated for a wide range of values of the condenser 48 or of the coil 46. Alternatively, the coil 46 may be so chosen as to have suitable resonant properties without the use of a discrete condenser 48.

The crystal may be applied to other parts of the system; untuned elements, such as resistors, for example, or elements resonant to a frequency widely different from the oscillation frequency, may be used. The element 40, for example, may be replaced by any other proper type of electrical apparatus in which the oscillation power is developed. In attempting to obtain oscillations, of course, one would always select proper parameters; and tuning the circuits by means of the condenser 48 is one way of obtaining such proper parameters.

Electric circuits have heretofore been produced with parameters having electrical characteristics such as to render the system stably non-oscillatory in the absence of a tuned element of the system and such as to render the system oscillatory when the tuned element is connected with the system. One of the prior-art circuits, for example, comprised a tuned element in the grid circuit and another tuned element in the plate circuit, the grid and plate circuits being uncoupled except for the capacity coupling between the grid and the plate. Such circuits, as is well known, will not oscillate unless proper circuit elements are chosen. In the oscillator herein shown, one of the said tuned elements of the prior art may be replaced by the electromechanical vibrator in the grid circuit, for example, as illustrated in the drawing. As in the case of the prior-art circuits, oscillations will or will not be produced, depending upon whether proper circuit elements have been chosen; but when oscillations are established, they will be of the frequency of the vibrator and highly constant.

For high frequencies, it is necessary to use the period determined by a small dimension of the specimen, as by its thickness, and this must be of the order of one millimeter for a frequency of 3,000 kilocycles per second.

An oscillator of the type described is mechanically limited as to exceedingly high frequencies, therefore, through inability to produce a crystal of the requisite thinness, which at the same time will be mechanically strong enough to permit handling and use. According to the present invention, however, the requisite high frequency may be obtained by combining a frequency multiplier with a master oscillator having a crystal of not excessive thinness; specifically, as illustrated, by coupling the frequency multiplier to the output of the oscillator so as to receive oscillatory energy therefrom. Incidentally, the frequency multiplier serves also as a power amplifier to amplify the signal strength, the frequency multiplier being operated at a harmonic relationship to the fundamental (or a harmonic) frequency of the master oscillator, thus making it possible to transmit at an enhanced harmonic frequency of the crystal-controlled oscillations of the master oscillator. The frequency multiplier is shown as comprising a vacuum tube 82 and its circuits, as will now be described.

The winding 40 is shown coupled to or interlinked with a winding 88 that is shunted by a tuning condenser 90. The elements 88 and 90 may be tuned so as to select or pick off from

the master oscillator one of the many harmonics of the fundamental frequency of vibration of the crystal 2. The grid or input circuit of the vacuum tube 92 in which the winding 88 is connected is biased by a battery 94 so as to impress a negative potential upon the grid 28 of the tube 92. A winding 96 is connected in the plate or output or anode circuit of the tube 92, and is coupled to a radiating antenna 56 through an antenna coil 52 that is connected, in series with a hot-wire ammeter 54, and through a variable condenser 58, to the ground. The antenna circuit constitutes an output or load circuit coupled to the output circuit of the frequency multiplier for receiving the increased or enhanced or amplified harmonic-frequency energy of the oscillations of the master oscillator.

The plate or output circuit of the tube 92, containing the coil 96, is tuned or made resonant by the condenser 58 to a harmonic of the frequency of the master oscillator, by virtue of its coupling to the circuit of the coil 52, which is connected to the antenna-to-ground capacity. This will be understood when it is reflected that the phase relation of the voltage across the coil 96 to the current that flows through it, at any given frequency, is in part determined by the adjustment of the condenser 58. At any given impressed frequency, therefore, there is a setting of the condenser 58 that brings the current in the coil 96 and the voltage across the coil 96 in phase. At this setting of the condenser 58, the anode circuit of the tube 92 is tuned to the impressed frequency. This frequency is practically the same as that to which the antenna circuit itself is resonant. For frequencies other than that to which the anode circuit is resonant, this anode circuit exhibits reactance and this reactance is either negative or positive, depending upon whether the frequency is higher or lower than the said resonant frequency.

By tuning the coil 52 through the medium of adjusting the condenser 58, therefore, the antenna circuit may be tuned so as to pick off a harmonic frequency of the oscillations in the circuit of the vacuum tube 24. The tube 92 and its circuits thus constitute a frequency multiplier. Any desired number of such amplifying units may be interposed between the master oscillator and the antenna to form an amplifier train without in any way departing from the present invention. Energy of the harmonic frequency in the output circuit thereof may be radiated through the antenna 56, or it may be amplified to other circuits in which it may be radiated or otherwise utilized. The crystal prevents variation in the frequencies of the currents of the tuned circuits of the master oscillator and, therefore, of the frequency multiplier also.

The vibrator 2 determines the frequency of oscillation of the master oscillating circuit comprising the vacuum tube 24. The master oscillator, which may be of, say, 5 watts, controls, through power amplification of the fundamental or a harmonic, the tube 92 that is adapted to yield an output of much higher power, say 50 watts, and so forth. Such a system has been successfully operated by me in practice over a considerable distance. I have constructed apparatus, according to the present invention, for fundamental frequencies ranging from 35 kilocycles per second to 3000 kilocycles per second. I have utilized harmonics of the device at frequencies of 20,000 kilocycles per second, corresponding to an electric wave of fifteen meters wave length. This range may undoubtedly be extended in both directions.

By gradually varying the air gap between the electrode 12 and the surface 6 of the crystal 2 to vary the frequency of the piezo-electric device 2, corresponding changes will be effected in the before-mentioned multiplied or harmonic frequency within predetermined limits. The same result may be brought about by means of other variable impedances. As explained in the said application, and also in application, Serial No. 549,830, filed July 10, 1931, other variable impedances than an air gap may be connected in series with the crystal. The frequency of the oscillations will be multiplied by a predetermined integer through the medium of the harmonic producer; and variation of the impedance will effect variations in the vibratory period of the crystal to produce variations in the frequency of the harmonics.

The crystal-controlled master oscillator, the frequency multiplier coupled thereto, and the radiating antenna having now been described, it remains to describe the means for modulating the oscillations in order that the harmonic-frequency energy appearing in the antenna or load circuit may bear signal modulations. This modulating means may take any desired form, and several forms, including a telegraph key, are described in the said application. According to the illustrated embodiment of the invention, however, the primary winding 68 of the modulation transformer is shown connected to the microphone 70, in circuit with a source of energy, shown as a battery 72.

The variations produced by the microphone modulate the carrier oscillations of the system; the modulated oscillations are impressed on the circuit 88, 90, which, as before stated, is tuned to a harmonic frequency of vibration of the crystal 2; the harmonically related oscillations are increased in amplitude by reason of the fact that the tube 92 acts both as an amplifier and a harmonic producer; and the modulated amplified oscillations of harmonic frequency are then transmitted to the antenna by the coils 96 and 52. The microphone 70 thus causes signal modulation of the energy of harmonic frequency to appear in the load circuit. The operation will be understood by persons skilled in the art without further description.

If the transmission is applied to a telephone line, the antenna-and-ground connections may be replaced by the well known connections to line wires.

Though the invention is illustrated in connection with a radio telephone, corresponding connections for transmitting by telegraph will be obvious to those skilled in the art. Both in telegraphy and telephony, the oscillations of the system will be kept at practically constant frequency by the vibrator, making it possible, for example, to use a very high frequency, with all the advantages flowing therefrom.

Modifications within the scope of the present invention will readily occur to persons skilled in the art. It is therefore desired that the above-described embodiment of the invention shall be regarded as illustrative of the invention, and not restrictive, and that the appended claims be construed broadly, except insofar as it may be necessary to impose limitations in view of the prior art.

What is claimed is:

1. In an oscillatory system, the combination of a plurality of electron tubes each having input and output circuits, said circuits interconnecting said tubes to form an amplifier train, one of said tubes being arranged for the generation of high-frequency oscillations, another of said tubes being arranged to multiply the frequency of said oscillations, and a piezo-electric crystal for controlling the frequency of the high-frequency oscillations.

2. An oscillatory system having, in combination, a vacuum tube having three electrodes, namely, a cathode, a grid and a plate, a source of energy, an output circuit including said plate and said cathode, an input circuit including said grid and said cathode, a piezo-electric crystal, means connecting the source in the first-named circuit and connecting the crystal with two of the electrodes to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal and such as to render the system stably non-oscillatory when not under the control of the crystal, a second vacuum tube having an input circuit and an output circuit, the input circuit of the second vacuum tube being arranged to receive oscillatory energy from the output circuit of the first-named vacuum tube, and means in a circuit of the second vacuum tube for enhancing a harmonic frequency of the oscillations of the first-named vacuum tube.

3. A frequency selector and amplification system comprising an electron tube for generating high frequency oscillations, a piezo electric crystal connected to said electron tube for stabilizing the frequency of said electron tube, circuits connected to the output of said electron tube for selecting a harmonic frequency of the fundamental frequency of said piezo electric crystal, and connections between the output circuit of said electron tube and another electron tube effecting an increase in amplitude of the harmonic frequency thus selected.

4. In a transmitter system, the combination of a signal transmission circuit, a piezo electric crystal element, an electron tube having input and output circuits, the input circuit of said electron tube connected to said piezo electric crystal element, said electron tube having means connected into its output circuit for selectively and independently sustaining a plurality of harmonics of the fundamental frequency of said piezo electric crystal element, an amplification system, a tuned circuit coupling said amplification system with said aforementioned means and adjustable to selectively amplify any one of the harmonic frequencies of said piezo electric crystal element selected and sustained by said aforementioned means, and connections between said amplification system and said transmission circuit for impressing the selected harmonic frequencies of increased amplitude upon said transmission circuit.

5. An oscillatory system having, in combination, a vacuum tube having an input circuit and an output circuit, a source of energy, an electromechanical vibrator, means connecting the source in the output circuit and the vibrator in the input circuit to constitute a self-oscillating system the frequency of the oscillations of which, when the system oscillates, will be substantially constant and determined by a mode of vibration of the vibrator, the electrical parameters of the system being such as to render the system stably non-oscillatory when not under the control of the vibrator, means for tuning the output circuit, a further circuit coupled to the output circuit, and means for tuning the further circuit to a hormonic frequency of the self-oscillating system.

6. An oscillatory system having, in combination, a vacuum tube having an input circuit and an output circuit, a source of energy, an electromechanical vibrator, means connecting the source in the output circuit and the vibrator in the input circuit to constitute a self-oscillating system the frequency of the oscillations of which, when the system oscillates, will be substantially constant and determined by a mode of vibration of the vibrator, the electrical parameters of the system being such as to render the system stably non-oscillatory when not under the control of the vibrator, means for tuning the output circuit, a second vacuum tube having an input circuit and an output circuit, the input circuit of the second vacuum tube being coupled to the output circuit of the first-named vacuum tube, means for tuning the input circuit of the second vacuum tube to a harmonic frequency of the self-oscillatory system, an antenna connected with the output circuit of the second vacuum tube, and means for tuning the output circuit of the second vacuum tube for maximum current.

7. In a signaling system, a multi-electrode tube having connected to the electrodes thereof a plurality of circuits, a piezo-electric crystal coupled to one of said circuits, a source of energy, means connecting the tube, the circuits, the source and the crystal together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the crystal at a substantially constant frequency determined by a fundamental mode of vibration of the crystal and such as to render the system stably non-oscillatory when not under the control of the crystal, whereby substantially constant-frequency oscillations of a fundamental frequency are produced by said tube and circuits, an electron-discharge device having an input circuit and an output circuit, the input circuit of said device being tuned to a harmonic frequency, means for feeding energy from said tube oscillator to said harmonically tuned circuit, a load circuit, means for coupling said load circuit to the output circuit of said electron-discharge device, whereby energy of harmonic frequency is fed to said load circuit, and means for causing signal modulation of the energy of harmonic frequency appearing in said load circuit.

8. In a signaling system, a multi-electrode-tube oscillator having a frequency-controlling circuit including a piezo-electric crystal and a tuned output circuit, said tube oscillator producing oscillations of a fundamental frequency, an electron-discharge-device amplifier having a tuned input circuit and an output circuit, said tuned input circuit being tuned to a harmonic of the fundamental frequency of oscillation of said tube oscillator, a load circuit coupled to the output circuit of said electron-discharge-device amplifier; means for feeding energy from said tube oscillator to said harmonically tuned input circuit, whereby amplified harmonic frequency energy appears in said load circuit, and means for causing the harmonic-frequency energy appearing in said load circuit to bear signal modulations.

9. In a signaling system, the combination of a plurality of electron tubes each having input and output circuits, with the output circuit of one of said tubes interlinked with the input circuit of a succeeding tube, one of said tubes being arranged for the generation of high-frequency oscillations, a piezo-electric crystal for controlling the constancy of the high-frequency oscillations, another of said tubes being arranged to multiply the frequency of said oscillations, and means for modulating the oscillations of increased frequency thus developed.

10. In a signaling system, the combination of a plurality of electron tubes each having input and output circuits, with the output circuit of one of said tubes interlinked with the input circuit of a succeeding tube, one of said tubes being arranged for the generation of high-frequency oscillations, a piezo-electric crystal for controlling the constancy of the high-frequency oscillations, another of said tubes being arranged to multiply the frequency of said oscillations, means for impressing a negative potential upon the input circuit of said last mentioned tube, and means for modulating the oscillations of increased frequency.

11. In a signaling system, the combination of a plurality of electron tubes each having grid, filament and plate electrodes, input and output circuits interconnecting said electrodes, means interlinking the output circuit of one of said tubes with the input circuit of a succeeding tube, said first-mentioned tube having means for the generation of high-frequency oscillations, a piezo-electric crystal for controlling the constancy of the high-frequency oscillations, the next-adjacent tube having means for multiplying the frequency of the oscillations thus developed, means for increasing the amplitude of the oscillations thus developed, means for impressing a negative potential upon the grid electrode of said second-mentioned tube, and means for modulating the oscillations of increased frequency thus developed.

12. In a signaling system, the combination of a plurality of electron tubes each having grid, filament and plate electrodes, input and output circuits interconnecting said electrodes, means interlinking the output circuit of one of said tubes with the input circuit of a succeeding tube, said first-mentioned tube having means for the generation of high-frequency oscillations, a piezo-electric crystal for controlling the constancy of the high-frequency oscillations, the next-adjacent tube having means for multiplying the frequency of the oscillations thus developed, means for increasing the amplitude of the oscillations thus developed, and means for modulating the amplitude of oscillations of increased frequency.

13. The combination of an electron-discharge device comprising a grid, a cathode and an anode, an anode circuit connected between said cathode and anode, a single piezo electric element connected in circuit with said grid, and a second electron-discharge device provided with a grid circuit coupled to said anode circuit and with an anode circuit, one of the last-named circuits being tuned to a frequency which is a harmonic of the resonant frequency of said element.

14. The combination of a tuned circuit, an electron-discharge device provided with a cathode and anode connected in said circuit and with a grid for controlling the transmission of current between said cathode and anode, a single piezo electric element connected between said cathode and grid, a second electron discharge device provided with a grid circuit coupled to said tuned circuit and with an anode circuit, and means for tuning the grid circuit to a frequency which is a harmonic of the resonant frequency of said element.

15. An oscillator comprising a pair of electron-discharge devices provided with anode circuits and with grid circuits, means for tuning the circuits of one of the devices to a harmonic of the frequency of the circuits of the other device, means for coupling one of said anode circuits to one of said grid circuits, and a piezo-electric element connected in the other of said grid circuits for preventing variation in the frequencies of the currents in said tuned circuits.

16. A radio transmitter having, in combination, a vacuum tube having three electrodes, namely, a cathode, a grid and a plate, a source of energy, a circuit including said plate and said cathode, another circuit including said grid and said cathode, a piezo-electric crystal, means connecting the source in the first-named circuit and connecting the crystal with two of the electrodes to constitute a master oscillator, the parameters of the master oscillator having electrical characteristics such as to render the master oscillator oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal and such as to render the master oscillator stably non-oscillatory when not under the control of the crystal, a frequency multiplier coupled to the master oscillator, means for modulating the oscillations, an output circuit coupled to the frequency multiplier, and a radiating antenna connected with the output circuit.

17. A radio transmitter having, in combination, a vacuum tube having three electrodes, namely, a cathode, a grid and a plate, a source of energy, a circuit including said plate and said cathode, another circuit including said grid and said cathode, a piezo-electric crystal having two electrodes only, means connecting the source in the first-named circuit, means connecting one of the crystal electrodes with one of the tube electrodes and the other crystal electrode with another tube electrode to constitute a master oscillator in which the two crystal electrodes will act conjointly for both stimulation and response, the parameters of the master oscillator having electrical characteristics such as to render the master oscillator oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal, a frequency multiplier coupled to the master oscillator, means for modulating the oscillations, an output circuit coupled to the frequency multiplier, and a radiating antenna connected with the output circuit.

18. A radio transmitter having, in combination, a vacuum tube having three electrodes, namely, a cathode, a grid and a plate, a source of energy, a circuit including said plate and said cathode, another circuit including said grid and said cathode, a piezo-electric crystal, means connecting the source in the first-named circuit and connecting the crystal in the second-named circuit to constitute a master oscillator, the parameters of the master oscillator having electrical characteristics such as to render the master oscillator oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal and such as to render the master oscillator stably non-oscillatory when not under the control of

the crystal, a frequency multiplier coupled to the master oscillator, means for modulating the oscillations, an output circuit coupled to the frequency multiplier, and a radiating antenna connected with the output circuit.

19. A radio transmitter having, in combination, a vacuum tube having three electrodes, namely, a cathode, a grid and a plate, a source of energy, a circuit including said plate and said cathode, another circuit including said grid and said cathode, a piezo-electric crystal, an impedance, means connecting the source in the first-named circuit and connecting the crystal and the impedance in parallel relation in the second-named circuit to constitute a master oscillator, the parameters of the master oscillator having electrical characteristics such as to render the master oscillator oscillatory under the control of the crystal at a substantially constant frequency determined by a mode of vibration of the crystal and such as to render the master oscillator stably non-oscillatory when not under the control of the crystal, a frequency multiplier coupled to the master oscillator, means for modulating the oscillations, an output circuit coupled to the frequency multiplier, and a radiating antenna connected with the output circuit.

20. A radio transmitter having, in combination, a vacuum tube having three electrodes, namely, a filament, a grid and a plate, a source of energy, a piezo-electric body, means connecting the source between the filament and the plate and the body with two of the electrodes to produce a master oscillator the frequency of the oscillations of which, when the master oscillator oscillates, shall be substantially constant and determined by a mode of vibration of the body, the electrical parameters of the master oscillator being such as to render the master oscillator stably non-oscillatory when not under the control of the body, the master oscillator having an input circuit connected between the filament and the grid and an output circuit connected between the filament and the plate, means for tuning the output circuit to a frequency determined by a fundamental mode of vibration of the body, a power amplifier having an input circuit and an output circuit, the amplifier input circuit being coupled to the output circuit of the master oscillator, means for tuning the power amplifier to a harmonic frequency of the master oscillator, means for modulating the oscillations, an output circuit coupled to the amplifier output circuit, and a radiating antenna connected with the output circuit coupled to the amplifier output circuit.

21. A radio transmitter having, in combination, a vacuum tube having an input circuit and an output circuit, a source of energy, a piezo-electric body, means connecting the source in the output circuit and the body in the input circuit to produce a master oscillator the frequency of the oscillations of which, when the master oscillator oscillates, will be substantially constant and determined by a mode of vibration of the body, the electrical parameters of the master oscillator being such as to render the master oscillator stably non-oscillatory when not under the control of the body, means for tuning the output circuit to a frequency determined by a fundamental mode of vibration of the body, a power amplifier having an input circuit and an output circuit, the amplifier input circuit being coupled to the output circuit of the master oscillator, means for tuning the power amplifier to a harmonic frequency of the master oscillator, means for modulating the oscillations, an output circuit coupled to the amplifier output circuit, and a radiating antenna connected with the output circuit coupled to the amplifier output circuit.

22. An oscillatory system having, in combination, an amplifying relay, a source of energy, an electromechanical vibrator, means connecting the relay, the source and the vibrator together to constitute an oscillatory system, the parameters of the system having electrical characteristics such as to render the system oscillatory under the control of the vibrator at a substantially constant frequency determined by a mode of vibration of the vibrator, and such as to render the system stably non-oscillatory when not under the control of the vibrator, a secondary circuit associated with the system, and means for adjusting the secondary circuit so as to take energy at a harmonic frequency from the system.

23. The combination of an oscillator of alternating current, a frequency multiplier coupled to said oscillator, a piezo-electric device for controlling the frequency of the oscillator, and means for gradually varying the frequency of the piezo-electric device to effect corresponding changes in the multiplier frequency.

24. A system for generating an alternating-current wave of a frequency within the limits of a predetermined band, comprising a source of oscillations, a frequency multiplier, means for connecting the multiplier to said source of oscillations to multiply the frequency thereof by a predetermined integer, and piezo-electric means for gradually varying and controlling the multiplier frequency.

25. The combination of an electrical oscillator, a harmonic producer for producing a harmonic of the frequency of said electrical oscillator, a piezo-electric device, means connecting the piezo-electric device with said electrical oscillator for determining the frequency thereof, and means for gradually varying the period of said piezo-electric device to vary the frequency of the harmonics.

26. The combination of an electrical oscillator, a harmonic producer for producing a harmonic of the frequency generated by said electrical oscillator, and a piezo-electric device connected with the oscillator for gradually varying the resultant frequency of the harmonic producer within predetermined limits.

27. The combination of an electrical oscillator, a harmonic producer for producing a harmonic of the frequency of said electrical oscillator, a piezo-electric crystal for determining the frequency of said electrical oscillator, and a variable impedance in series with said piezo-electric crystal, said impedance being varied to effect a corresponding variation in the vibratory period of said piezo-electric crystal to vary the frequency of the harmonics.

28. An oscillatory system having, in combination, an alternating-current circuit, an electromechanical vibrator connected with the circuit, means connecting the circuit with the vibrator to maintain the frequency of the circuit substantially constant, the electrical constants of the system being of such value and kind as will enable the vibrator to be the sole control of the frequency, an impedance in series with the vibrator, means for varying the impedance to vary the constant frequency, a second electric circuit, and means for transferring energy from the first-named circuit to the second circuit at a harmonic frequency.

29. An oscillatory system comprising a master oscillator having a tube provided with three electrodes, namely, a filament, a grid and a plate, a piezo-electric crystal, means connecting the crystal between the grid and the filament to maintain the oscillations of the system at the substantially constant frequency of a mode of vibration of the crystal, the electrical constants of the system being of such value and kind as will enable the vibrator to be the sole control of the frequency, an impedance in series with the vibrator, means for varying the impedance to vary the constant frequency, a secondary power circuit associated with said master oscillator, and means for transferring energy at a harmonically related frequency from the tube circuit to said power circuit.

GEORGE W. PIERCE.

APPENDIX L

U. S. Patent No. 1,472,583, October 30, 1923

(See Pages 127 to 132 Opposite ☞)

127

Oct. 30, 1923. 1,472,583

W. G. CADY

METHOD OF MAINTAINING ELECTRIC CURRENTS OF CONSTANT FREQUENCY

Filed May 28, 1921

Fig. 1.

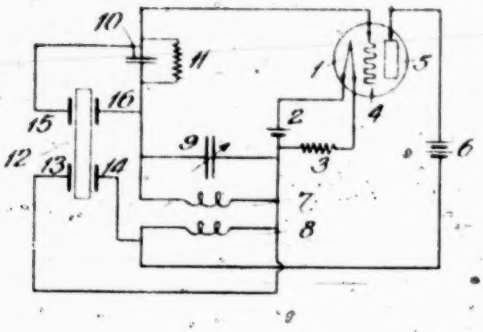


Fig. 2

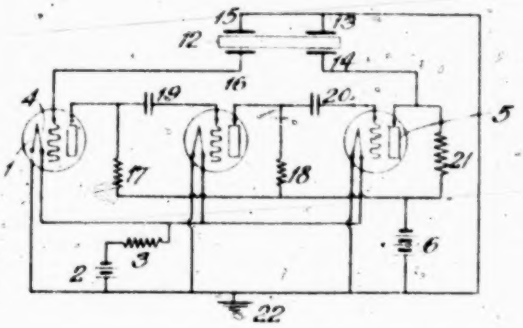


Fig. 3.

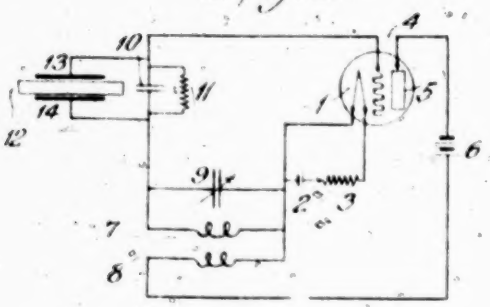


Fig. 5

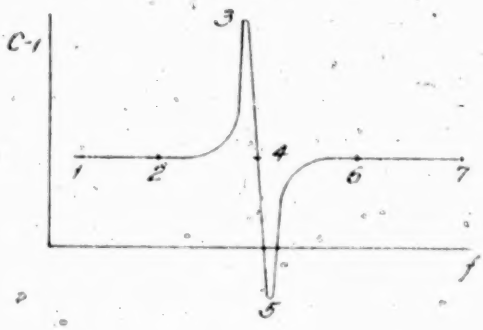


Fig. 4.

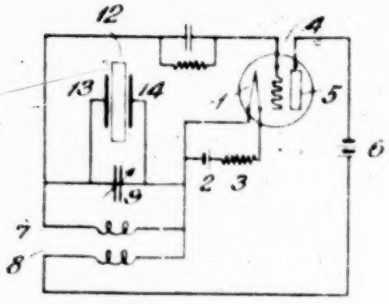
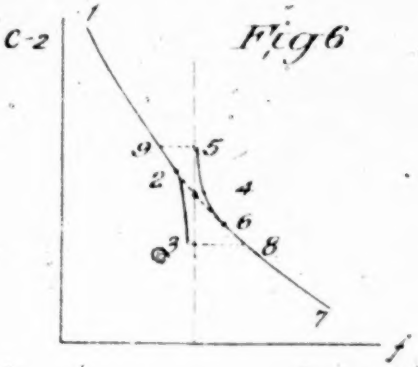


Fig 6



Inventor:
Walter G. Cady

By his Attorneys
Kerr, Page, Cooper & Hayward

Patented Oct. 30, 1923. 1,472,583

UNITED STATES PATENT OFFICE.

WALTER GUYTON CADY, OF MIDDLETOWN, CONNECTICUT.

METHOD OF MAINTAINING ELECTRIC CURRENTS OF CONSTANT FREQUENCY.

Application filed May 28, 1921. Serial No. 473,434. REISSUED

To all whom it may concern:

Be it known that I, WALTER G. CADY, a citizen of the United States of America, residing at Middletown, in the county of Middlesex, State of Connecticut, have invented certain new and useful Improvements in Method of Maintaining Electric Currents of Constant Frequency, of which the following is a full, clear, and exact description.

The invention which forms the subject of my present application for Letters Patent is an improvement in the art of producing and maintaining alternating currents of constant frequency. It is well known that heretofore the development of such currents to any very high degree of precision has been unattainable by ordinary means and great difficulty has been experienced in producing alternating currents of high and constant frequency and free from fluctuations due to disturbances in or near the generating system.

The useful applications of my invention are numerous. It may be employed in the transmission or the reception of intelligence by means of high frequency currents, or it may be used for the testing and measurement of such currents and of those in circuits associated therewith in all cases where the frequency may be controlled by the electrical constants of the system, and, in general, the invention is applicable to currents of any frequency.

In an application filed by me on Jan. 28, 1920, Serial No. 354,659, which has matured into Patent No. 1,450,246, April 3, 1923. I have shown and described what I have termed a piezo-electric resonator, which, in general, comprises a plate of piezo-electric crystal with coatings on its opposite face. Such a device has a natural period of vibration, but when set in vibration by a source of alternating current connected to its coating, the amplitude of such vibrations is very slight unless the frequency of the alternating current approximates or equals the natural or critical frequency, in which case the reaction of the deformed crystal upon the circuit may be such as to practically choke back the alternating current. In carrying out my present invention I utilize this piezo-electric resonator in the manner hereinafter to be described.

The special properties of the piezo-electric resonator that I take advantage of for my present purpose are—first: that property by virtue of which such a resonator, whose vibrations are maintained by impulses; received from one electric circuit, may be used to transmit energy in the form of an alternating current into another circuit; second, that property which it possesses of modifying by its reactions the alternating current of a particular frequency or frequencies flowing to it; and third, the fact that the effective capacity of the resonator depends, in a manner which will more fully hereinafter appear, upon the frequency of the current in the circuit with which it may be connected.

In the description and explanations of my invention which follow, I have assumed the piezo-electric resonator to comprise a single suitably prepared plate cut from a piezo-electric crystal, and provided with the usual coatings, and utilizing the so-called transverse effect; but all statements made apply equally to crystal preparations utilizing the longitudinal effect, and in general, to any mechanical vibrating system whatever, having suitable preparations of piezo-electric crystals for setting the system into vibration and for utilizing its reactions.

The nature and purpose of the invention may be most readily comprehended by reference to the diagrams which I have used in its explanation and which are exhibited in the accompanying drawing.

In this drawing:—

Fig. 1 is a diagram of the well known and universally recognized Armstrong oscillating circuit, selected for illustrative purposes and showing my invention applied thereto;

Fig. 2 is a diagram of a three-stage amplification system of well-known type, with my invention applied thereto;

Figs. 3 and 4 are other diagrams similar to Fig. 1 illustrating further modifications; and

Figs. 5 and 6 are diagrams used in explaining the principles of the invention.

The above described diagrams are illustrative examples of various ways in which a piezo electric resonator may be employed to maintain constant frequency in an oscillatory electric circuit. It will be understood that they do not purport to show the only possible arrangements for securing

this result, and even as to those shown it will be further understood that the illustrated arrangements may be modified in various ways which, however, are obvious to those skilled in the art and familiar with high frequency apparatus and which will not alter the essential part played by the piezo-electric resonator.

I shall assume, for purposes of this case, that in each case the high frequency oscillations are produced through the agency of the three electrode vacuum tube of the type commonly used in radio-telegraphy, but I may state that this is not essential and that the only requirement is that the source of energy shall be capable of generating currents of a frequency determined or controlled by the electric constants of the oscillating circuit, and when I use the term "coatings" in referring to the resonator I mean either thin layers of metal on the crystal itself, or metallic plates in fixed relation to the crystal; or, in general, any means whereby an electric charge may be conducted to the resonator in such a way as to produce an electric field in the proper direction through the crystal.

With the above understanding I now refer to Fig. 1. In this figure the numeral 1 represents the filament of the vacuum tube, 2 is the filament battery, 3 a regulating resistance, 4 the grid and 5 the anode of the vacuum tube. The battery in the anode circuit is designated by 6. These are the main essential parts of one of the numerous types of circuit commonly used for the generation of high frequency oscillations, the other elements being the coils 7 and 8 in the grid and anode circuits respectively, 9 a variable condenser in parallel with the coil 7 for the purpose of controlling the frequency of the oscillations, 10 the grid condenser, and 11 the leak. All these are old and well known.

The plate or crystal of the piezo-electric resonator is indicated by 12 and this plate has four coatings 13, 14, 15 and 16, the two former being connected to the terminals of the coil 8, the two latter to the grid circuit around the condenser 10.

The operation of the system is as follows: When the coupling between the two coils 7 and 8 is of proper character or value, the circuit oscillates with a frequency determined, in the main, by the capacity of condenser 9, and the self-inductance of the coil 7. If the capacity of condenser 9 be varied, the frequency changes, and when a rate is reached corresponding to one of the natural modes of vibration of the piezo-electric resonator, the latter begins to vibrate by reason of the electric field existing between the coatings 13 and 14. These vibrations through the piezo-electric action, cause electric charges to be induced on the coatings 15 and 16, which in turn alter the potential difference across the condenser 10, and hence the potential of the grid itself.

Whether amplitude of the potential of the grid be thereby increased or diminished, depends upon which of the coatings 15 or 16 is connected to the grid, and upon the phase relations in the electric circuits and in the piezo-electric resonator itself.

The phase of the vibration of the resonator is modified by the fact that the potential difference between the coatings 15 and 16 is influenced by the periodic voltage already existing across the condenser 10. In order to effect the maximum reinforcement of the oscillations, it may be advisable to control the phase of the vibrations of the resonator. This may be done, for example, by giving the coil 8 a certain resistance, or by inserting in series with the coil 8 another inductance and a resistance and connecting the coatings 13 and 14 in parallel with such inductance and resistance instead of in parallel with the coil 8.

The frequency of the electric oscillations as determined by the inductance of coil 7 and the capacity of the condenser 9, may be that of the fundamental vibration of the piezo-electric resonator, or of one of its harmonics. In any case, the two pairs of coatings on the resonator should have such a size and position relatively to the ends of the crystal plate, as to cause the greatest possible amplitude of vibration at the desired frequency. It is also of great importance that the coating be so disposed, and the plate so supported that the vibrations shall be damped as little as possible.

If, under the conditions assumed, while the oscillations are being reinforced through the vibrations of the piezo-electric resonator, and at any of the frequencies mentioned above, the coupling between coils 7 and 8 be loosened to such a degree that the circuit, with the resonator absent, would just fail to oscillate, with the resonator present it will be found that the oscillations still persist; and, moreover, that a variation in the capacity of the condenser 9 over a certain range has no appreciable effect upon the frequency in the circuit. In other words, this frequency is determined solely by the period of vibrations of the resonator itself. It is, as a matter of fact, often an advantage to make the capacity of condenser 10 very small, or even to omit it altogether.

I have found that all of those factors that usually have a disturbing effect upon the frequency, as for example, variations in the voltage of either of the batteries 2 or 6, or movements of the hand near the circuit, are, by the use of the piezo-electric resonator and within wide limits, without effect upon the frequency.

The piezo-electric resonator may be used

in connection with other types of oscillating circuit than the one above described. In accordance with the principle of operation set forth above, it may be used with any generator of alternating current, the frequency of which is capable of being determined by the varying potential difference between two fixed points in the circuit or system of circuits.

The greater the amplification constant of the vacuum tube, the more widely may the electrical constants of the circuit be altered without affecting the frequency. For this reason a still greater degree of stability may be attained by the use of a plurality of tubes connected for cascade amplification. I have found, for instance, that by the use of a cascade amplifier comprising three tubes, the coils 7 and 8 and the condenser 9 may be entirely dispensed with.

This arrangement of circuit is shown in Fig. 2, in which 4 represents the grid of the first tube and 5 the anode of the third. Two resistances 17 and 18 are employed, and two condensers 19 and 20. This illustrates the well known "resistance amplification," but any other type of amplificator might be employed. In this figure, 21 is a resistance or other impedance in the anode or output circuit, while the piezo-electric resonator 12 has its two coatings 13 and 14 connected to the plate 5, and the ground 22, respectively, and its two coatings 15 and 16 connecting the one to the ground 22, and the other to the grid 4.

The operation of this arrangement is as follows: Any slight increase in the potential of the anode 5 by altering the electric field between the plates 13 and 14 sets the piezo-electric resonator in vibration. The charges thereby excited in the coatings 15 and 16 vary the potential of the grid 4 with respect to the ground 22. This varying potential by virtue of the amplification taking place in the system, will, if the proper coating is connected with the grid 4, still further increase the variations in the potential of the anode 5 and maintain the piezo-electric resonator in vibration. From the terminals of the resistance or impedance 21, a small amount of output power at a constant frequency may be drawn.

It is possible to secure constant frequency through the agency of a piezo-electric resonator which has only a single pair of plates or coatings, and this may be accomplished in various ways by taking advantage of one or the other of the electrical effects produced by the resonator when approximating one of its resonating frequencies. For instance, as shown in Fig. 3, which is exactly like the arrangement shown in Fig. 1, except that the piezo-electric resonator 12, has but one pair of coatings 13 and 14, which are connected in parallel with the condenser 10. If the capacity of the resonator be sufficiently large, the condenser may even be dispensed with.

In explanation of the action which takes place in this case, let it be assumed that the coupling between the coils 7 and 8 be loosened, as by increasing the distance between the two, until the circuit just fails, in the absence of the piezo-electric resonator 12 to oscillate. When the resonator is present, however, and the capacity of the condenser 9 is not too far from the value which would, with closer coupling, make the circuit oscillate at the same frequency as that of the vibrations of the resonator, the circuit will be found to be oscillating. The oscillations in this case are due to the vibration of the resonator 12 and are of a frequency that is stable against disturbing influences, provided those latter be not too pronounced.

The theory of this segmentive action may be stated as follows: Suppose that, owing to some slight mechanical jar or electrical disturbance, the resonator is set into feeble vibrations. Through the piezo-electric action, these vibrations cause corresponding changes in the potential of grid 4, Fig. 3, which, in turn—owing to the amplfying action of the vacuum tube and its associated circuits, cause similar pulsating currents in the coil 7. These pulsating currents influence the changes on the coatings of the resonator and tend to maintain the vibrations of the latter. Since the resonator is supposed to have been set into vibration by a somewhat sudden disturbance, it follows, in accordance with well known principles, that its vibrations, and consequently the effect which it produces, as indicated above in the coil 7, do not possess simply a single frequency, but may be considered as a combination of many frequencies of slightly different values. Of these different frequencies, that one predominates which is associated with maximum fluctuations of grid potential. I have shown, theoretically (Proceedings, Institute of Radio Engineers, vol. 10, p. 83, April, 1922), and verified by special experiments, that for the alternating electro-motive force acting in the circuit, the current flowing to the resonator is greatest at a frequency very slightly below the natural frequency of said resonator. Also, when the resonator current is greatest the consequent fluctuations in grid potential are naturally greatest. Hence with the circuit shown in Fig. 3, an alternating current of practically unvarying frequency will be built up and maintained in the system, of a frequency slightly lower than the natural frequency of vibration of the resonator.

The following example illustrates the applicability of the piezo-electric resonator to the stabilization of the frequency when connected across the tuning condenser of a

vacuum tube oscillating circuit. Now to understand this action, the theory of the piezo-electric resonator must be considered and borne in mind.

In my former application above referred to, I have shown that the apparent capacity of the piezo-electric resonator undergoes certain changes in the neighborhood of resonance, and these changes are of fundamental importance in the example now to be considered.

Let it be assumed, in illustration, that the resonator is connected to a high frequency sinusoidal electro-motive force of constant voltage. When the frequency is considerably below that at which the resonator vibrates, the latter behaves like a simple condenser, having a certain capacity, which may be termed its "normal" capacity. If and as the frequency is raised to a value at which the piezo-electro resonator begins to vibrate perceptibly, the elongation of the resonator plate is at first nearly in phase with the mechanical stress, which, in turn, is always exactly in phase with the voltage across the resonator. Hence, in accordance with the well known laws of piezo-electricity, the piezo-electric polarization resulting from the elongation is nearly in phase with the impressed voltage, thus causing the total dielectric displacement in the piezo-electric resonator to be greater than normal.

Since the apparent, or as it may be termed, the equivalent capacity of the resonator is, other things being equal, proportional to the total dielectric displacement, it follows that so long as the frequency is below the resonant value, the apparent capacity is abnormally large. It may, in fact, be many times in excess of the normal value. But after passing through a maximum, the apparent capacity decreases, and close to the resonant frequency it returns to its normal value. Upon a further increase in frequency the apparent capacity becomes abnormally small, in some cases even attaining a considerable negative value. If the frequency continues to increase, a minimum in the apparent capacity is reached, after which it gradually returns to its normal value.

I have represented these changes in the diagram of Fig. 5 in which the apparent capacity of the piezo-electric resonator, which may be denoted by C^1 is plotted as a function of the frequency f. Starting at a low value of frequencies the apparent capacity has its normal value represented by the point indicated by 1. As the frequency f increases, the apparent capacity C^1 remains approximately constant until at a frequency corresponding to the point 2, the resonator begins to vibrate perceptibly, and the curve begins to rise. The points 3, 4, 5, 6 and 7 are reached in succession, in accordance with the theory stated

Assume now, therefore, that the piezo-electric resonator be connected in parallel with the tuning condenser 9, as shown in Fig. 4. The diagram of this figure represents a vacuum tube circuit oscillating in the same manner as that shown in Fig. 1, through the mutual induction of the coils 7 and 8, the frequency being determined by the variable condenser 9. The coatings 13 and 14 of the resonator 12 are in parallel with the condenser 9.

Let the capacity of the condenser 9 be denoted by C^2. If the capacity C^1 were constant then a decrease in capacity C^2 would result in a continuous increase in the frequency f, as indicated in Fig. 6, by the curve 1, 9, 2, 4, 6, 8 and 7. Suppose, however, and observing that the corresponding points in Figs. 5 and 6 are similarly numbered, that the piezo electric resonator begins to vibrate perceptibly at a frequency corresponding to the point 2, thereupon the capacity C^1 begins to be abnormally large and therefore tends to diminish the frequency, with the result that the frequency increases less than it otherwise would. Continued decrease of the capacity C^2 causes capacity C^1 to increase still further, so that the curve bends down along the portions 2, 3. At point 3 the apparent capacity C^1 has reached its greatest possible value. If C^2 be further decreased the resonator plate suddenly ceases to vibrate, or at best it vibrates feebly at a much higher frequency, namely, the frequency corresponding to the point 8. In other words, the curve springs abruptly from the point 3 to the point 8. From this on, any further decrease in C^2 gives rise merely to the undisturbed portion 8, 7 of the curve. If, on the other hand, the capacity C^2 be increased, beginning at the point 7, the path 7, 8, 6, 5, 9, 1 will be traced, for reasons strictly analogous to those given for the curve described on decreasing the capacity C^2 as stated above.

The less damped the vibrations of the piezo electric resonator, the more nearly constant will be the frequency over the portions of the curve 2, 3 and 5, 6 in Fig. 6. Hence it is manifest that a resonator made from materials of good mechanical properties, such as quartz, or a combination of quartz and steel suitably prepared and mounted, as has been set forth in my prior application, will exert a marked stabilizing effect upon the frequency of the generating circuit with which it is connected. Any disturbing agent, as for example, small changes in the value of C^2 or in other capacities in the circuit, or variations in the filament current, will have almost no effect at all, upon the frequency, so long as such disturbing agent is not so pronounced as to cause the operating point on the curve to fall outside of the ranges 2, 3 and 5, 6.

Having now described my invention what I claim is:

1. The combination with an alternating current system of such nature that the frequency of the alternations is governed by potential variations in a portion of the same, of a means for keeping the frequency constant within very narrow limits, consisting of a piezo-electric resonator having its two conducting coatings so connected to the system that the said resonator is maintained in vibration by the electric oscillations in the system, and which by its reactions causes the frequency of said potential variations to be identical with that of its own mechanical vibrations.

2. The combination with a generating system of alternating current the frequency of which is capable of being determined by the varying potential difference between two fixed points therein, of a piezo-electric resonator having two pairs of coatings, one pair being so connected to the alternating current system that the said resonator is maintained in a state of vibration, while the other pair is connected to the said two fixed points so as to cause the generator to produce alternating current of a frequency identical with that of the mechanical vibrations of the said resonator.

3. The combination with an alternating current amplifier of a piezo-electric resonator having two pairs of conducting coatings, one pair connected to the output circuit of the amplifier, the other pair connected to the input circuit so as to cause in the output circuit an alternating current to flow the frequency of which is determined by the mechanical vibrations of the said resonator.

In testimony whereof I hereto affix my signature.

WALTER GUYTON CADY.

APPENDIX M

U. S. Patent No. 1,545,607, July 14, 1925

(See Pages 133 to 136 Opposite ☞)

133

July 14, 1925. 1,545,607

J. C. SCHELLENG

SYSTEM OF RADIO DISTRIBUTION

Filed Dec. 28, 1923

Fig. 1.

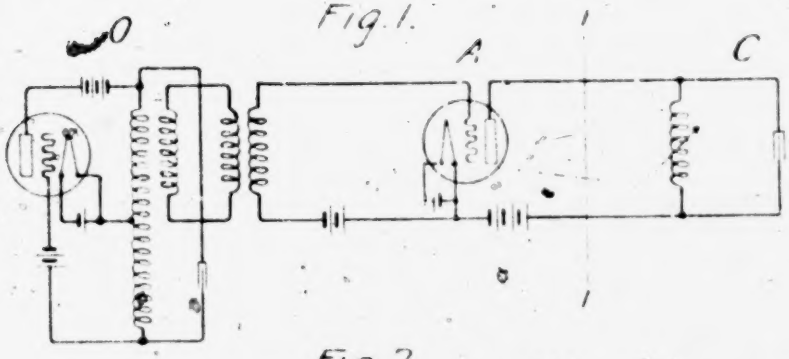


Fig. 2.

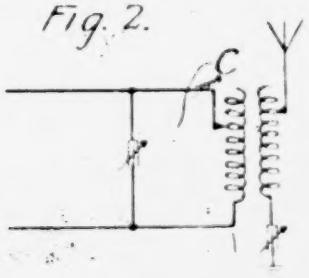
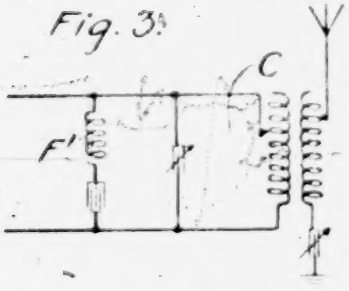


Fig. 3.



Inventor:
John C. Schelleng.
by Chas. Sprague Atty.

Patented July 14, 1925. 1,545,607

UNITED STATES PATENT OFFICE.

JOHN C. SCHELLENG, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

SYSTEM OF WAVE DISTRIBUTION.

Application filed December 28, 1920. Serial No. 433,660.

To all whom it may concern:

Be it known that I, JOHN C. SCHELLENG, a citizen of United States, residing at East Orange, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Systems of Wave Distribution, of which the following is a full, clear, concise, and exact description.

This invention relates to a system of wave distribution and particularly to an oscillator circuit arrangement for supplying variable current at constant frequency.

The particular object of the invention is to provide, in a high frequency system which includes an oscillator, a means for preserving the constancy of the frequency of the oscillations under varying conditions of load or tuning in circuits associated with said system and deriving energy therefrom.

A further object is to provide a means intermediate an oscillator and an energy absorbing circuit which renders the frequency of said oscillator independent of variations in load or tuning of said energy absorbing circuit.

A still further object of the invention is to provide an amplifier of a particular type between the oscillator and work circuits to prevent reaction therebetween.

The invention has application in a system for the generation and distribution of electrical energy in which an oscillator of the generic type in which the frequency of the oscillators is determined by the electrical constants of an oscillatory circuit associated therewith is used. In this general type the energy is transmitted from the oscillator by means of an oscillation circuit, to which the work circuit is related by a coupling to either the inductance or the capacitance element of the said circuit. In either case the associated work circuit, in effect, is a part of the oscillation circuit, and its electrical characteristics contribute to a determination of the natural period of oscillation of the circuit as a whole. For example, the work circuit may be, and usually is, inductively related to an inductive portion of the oscillation circuit of an oscillator. The inductance in this related work circuit enters as a factor into the term which expresses the mutual inductance of the transformer and hence is the equivalent of a calculated inductance inserted directly in the primary circuit, as it is represented in fact, in the simplified circuit of a transformer. Obviously, any change in the electrical conditions in this related circuit will change the fundamental frequency of the system.

In many arrangements of this class, an amplifier is inserted between the oscillator and the energy absorbing device or circuit, the oscillation circuit of the generator being coupled to the input circuit of the amplifier tube, the load being included in the output circuit. Any change in the load circuit as, when the tuning of this circuit is changed, results in a change in the input impedance of the tube, and hence in a variation of the oscillator frequency. That a change in the load, whether of degree or kind, effects a corresponding change in the input impedance has been demonstrated experimentally. A report of this, together with a mathematical analysis of circuit relations, may be found in Scientific Paper No. 351 of the U. S. Bureau of Standards.

This change in frequency can result from an increase or decrease in the loading of a power amplifier, a variation in the resistance included in the load circuit being attended by a corresponding change in the inductance always associated therewith. Or, the output circuit may include a closed oscillation circuit of a radio transmission system interposed between the amplifier tube and the radiating or antenna circuit. Such a system requires for efficient transmission of energy that the said oscillation circuit, as well as the antenna circuit, should be tuned to the high frequency that is being transmitted. In this case efforts to tune the oscillation circuit associated with the output of the tube will result in a change in the transmitting frequency.

The invention is designed to avoid the variations in oscillator frequency consequent upon any change whatever in the work circuit associated therewith, the examples given above being illustrative, only, of a large number of possible applications of the invention.

The method of the invention consists, in part, in causing the output circuit of the oscillator system to have very small, or substantially zero, impedance at the oscillator frequency. Under these conditions, a relatively great change in a component impedance included in the output circuit will produce no effect on the input impedance of

the tube and hence on the frequency of the oscillator. This result is accomplished by causing the output circuit, or a portion thereof constituting the work circuit, to be tuned to a higher frequency and by transmitting at this higher frequency. To this end the amplifier is of a particular type in which the product of amplification is a distorted wave containing a first even harmonic having a relatively great amplitude. The output circuit is tuned to this harmonic frequency which thus constitutes the frequency which is characteristic of the energy to be supplied by the generator unit as a whole, this unit consisting of the oscillator, amplifier tube, and associated circuits. If desired, a filter circuit which is resonant to the oscillator frequency may be placed in shunt across the output circuit. In either case there is substantially a short circuit path for the current of oscillator frequency and any change of condition in the work circuit, involving slight change in tuning to the higher frequency, does not affect the impedance of the output circuit to the lower frequency. The oscillator is accordingly undisturbed by normal adjustments of the work circuit.

For a more detailed disclosure of the principles of the invention, particularly as relating to its practical embodiment, reference is had to the description which follows, taken in connection with the accompanying drawings, in which Fig. 1 shows a system broadly embodying the invention. Fig. 2 shows that portion of the system of Fig. 1 included at the right of line 1–1 as applied to a specific use; and Fig. 3 shows a system of Fig. 2 provided with a filter circuit.

Referring to Fig. 1, the system as a whole consists of an oscillation generator O, the amplifier A and the load circuit C, the load circuit being capable of being tuned to a definite frequency by the means shown. The oscillator O, as has been pointed out, may be any one of the several types characterized in common by an oscillation circuit associated with the primary energy source which at the same time effects the necessary coupling between the two circuits for transfer of energy therebetween, and determines the frequency of the resulting oscillations. An example of a type of oscillator conforming to this generic principle is found in Hartley Patent 1,356,763, October 26, 1920.

The amplifier A differs from the conventional type which is designed to amplify with minimum distortion, in that it combines the usual function of an amplifier with that of a harmonic producer, and hence can be considered an amplifier in which the amplification is accompanied by relatively great distortion.

A common adaptation for using an amplifier tube as a harmonic generator consists in overloading the tube, by which is meant that the alternating variations of E. M. F. impressed on the grid are of such amplitude as to cause the tube to operate at a critical value of its grid potential, as at or beyond the "knee" of the characteristic curve, with resulting periodic distortion of the output wave. Although this, or any other mode of operation which produces a distorted wave is comprised within the bounds of the invention, it is preferred to use the other of the two general types, that in which a sufficient negative potential is impressed on the grid to bring its mean potential to a point close to the lower end of the characteristic curve. The alternating variations in grid potential will correspondingly occur between an upper limit which may be in a region of positive potential and a lower limit which is very close to the foot of the curve or even beyond this point. The method of operating the amplifier as above, results in a distorted space current wave in which is contained a relatively large component of the first even harmonic. This function results from the fact that a negative polarizing potential may be given a sufficient value to reduce the normal space current to a small value.

The work circuit C is tuned to a harmonic, for example, the first even harmonic of the generated wave. For example, if F is the frequency desired, the oscillator would be designed and adjusted for a frequency ½ F.

In Fig. 2 the work circuit is shown as the closed oscillation circuit of an antenna system, the radiating circuit being preferably tuned to the same frequency as the closed circuit by the variable means shown. The closed circuit is tuned to the harmonic frequency. Since the frequency to which the closed circuit is tuned is so different from the generator frequency, the impedance of the plate circuit, so far as this frequency is concerned, is very small. Hence only very small changes of generator frequency will occur when the impedance of the output circuit to frequency F is varied.

In Fig. 3, an additional means is shown for insuring that the impedance of the plate circuit to the oscillator frequency shall be very small. The means shown is the filter circuit F', which may be composed simply of an inductance and a capacitance in series and tuned to the oscillator frequency. This circuit, in effect, is a short circuit to circuit C for the fundamental frequency and the impedance of the output circuit, as a whole, is substantially zero to the oscillator frequency. Any slight variation of the values of the elements in circuit C, as an adjustment for precise tuning, accordingly does not affect the impedance of the pate circuit to the oscillator frequency.

Summarizing all of the above, the inven-

tion in its broadest aspect resides in causing the plate circuit to have zero, or substantially zero, impedance to the current of oscillator frequency. Since this feature taken alone, would be inconsistent with the use of the plate circuit as a work circuit, it is necessary to, in effect provide separate circuits for the oscillator frequency current and for the work current. This is accomplished in a simple way by tuning the work circuit to a different frequency than that of the oscillator frequency, thus insuring an energy flow from the system without sacrificing the essential requirement that the plate circuit have zero impedance to the oscillator frequency. In order to most efficiently extract energy from a system it is convenient to make the work circuit frequency correspond to a harmonic of the voltage wave impressed on the plate circuit, the first even harmonic being chosen since it is the most powerful of the harmonics making up the complex wave of the harmonic generator. It has been found that with the method here used of stepping up the frequency, efficiencies as high as 50% can be obtained when the load is tuned to the first even harmonic. This result amply demonstrates that it is practicable to step up the frequency in this way.

It should be understood that, although a single amplifier unit is shown, further amplification of the harmonic frequency may be secured by amplifiers inserted between the generator amplifier system shown and the work circuit, and that there may be as many stages of amplification as may be desired.

What is claimed is:

1. In combination, a primary energy source and an energy absorbing and frequency determined circuit associated therewith, said circuit comprising a wave distorting means for producing harmonics of the wave from said source, and a work circuit, said work circuit constituting a parallel resonant path for a harmonic frequency and including a series resonant path for the frequency from said source.

2. In a system of distribution, a source of oscillations including an oscillation circuit for determining the frequency supplied thereby, an audion amplifier associated with said source and having its input circuit energized by said oscillation circuit, the mean grid potential of said amplifier being adjusted so that the output current thereof has a first even harmonic of said frequency of materially greater amplitude than any other harmonic, a load circuit included in the space circuit of said amplifier and tuned to said harmonic frequency, and a filter circuit in shunt with said load circuit and tuned to resonance with the oscillation frequency.

3. In combination, an oscillation generator including an energy absorbing and frequency determining circuit, said circuit comprising means for efficiently transmitting a wave having a frequency widely different from the frequency determined by the constants of said circuit and having an impedance at that frequency which is substantially greater than zero, and including a series path which is resonant to the determined frequency.

4. In combination, a primary energy source including a frequency determining circuit, an output circuit, and means between said source and output circuit for deriving harmonics of the wave from said source, said output circuit comprising means for efficiently transmitting currents of a harmonic frequency and having an impedance at that frequency which is substantially greater than zero, said output circuit also comprising a series resonant path for the frequency of the current from said source.

5. In combination, a primary energy source including a frequency determining circuit, an output circuit, and means between said source and output circuit for converting the wave from said source to a wave having preponderately one harmonic, said output circuit having an impedance at the frequency of said harmonic which is substantially greater than zero and including a series resonant path for the frequency of the current from said source.

In witness whereof, I hereunto subscribe my name this 17th day of December, A. D. 1920.

JOHN C. SCHELLENG.